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Subject: ACTION: Final Economic Assessment, FMVSS No. 208, Advanced Air Bags

Date: MAY 4 2000

From: William H. Walsh (James E. Simons for)
Associate Administrator
for Plans and Policy

Reply to Attn. of:

To: Docket

Thru: Frank Seales (for)
Chief Counsel

Docket # NHTSA-00-7013
Notice 2

Please submit the attached copy of the "Final Economic Assessment, FMVSS No. 208, Advanced Air Bags," May 2000, to the appropriate docket.

Attachments

Distribution:
Associate Administrator for Safety Performance Standards
Associate Administrator for Research and Development
Associate Administrator for Safety Assurance
Chief Counsel

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U.S. Department
of Transportation

National Highway
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Administration

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FINAL ECONOMIC ASSESSMENT

FMVSS NO. 208
ADVANCED AIR BAGS

Office of Regulatory Analysis & Evaluation
Plans and Policy
May, 2000

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EXECUTIVE SUMMARY

This Final Economic Assessment analyzes the potential impact of new performance requirements and test procedures for advanced air bag systems. Consistent with the National Highway Traffic Safety Administration Re-authorization Act of 1998, which is part of the Transportation Equity Act for the 21st Century (TEA 21), the intent of this rulemaking is to minimize risks caused by air bags to out-of-position occupants, especially infants and children, and to improve occupant protection provided by air bags for belted and unbelted occupants of all sizes. To achieve these goals, NHTSA is requiring vehicles to meet test procedures that broaden the scope of the current standard to ensure that occupants are properly protected under a wider variety of crash circumstances.

Test Requirements

The risk of injury from air bags arises when occupants are too close to the air bag when it inflates. Generally, those most at risk from injury are infants, young children, and out-of-position drivers. To address these concerns, new tests employ crash dummies representing infants, 3-year olds, 6-year olds, and 5th percentile female drivers. There are a variety of tests to protect these at-risk occupants. These tests generally require either that the air bag be suppressed if certain risk conditions exist or that deployments occur at levels that produce a low probability of injury risk. For purposes of this analysis, it is assumed that manufacturers will choose the low-risk deployment option for drivers. On the passenger side, the costs and benefits of two options are examined. Option 1 assumes the automatic suppression test will be met by using a weight sensor for the infant, 3 and 6 year old dummies or a weight and presence sensor. Option 2 assumes a weight sensor for infants and a low-risk air bag for the 3 and 6 year old dummies for the out-of-position tests.

The assessment analyzes three alternative sets of high speed tests to preserve and enhance air bag protection. Each set of tests includes belted and unbelted full frontal perpendicular rigid barrier tests using 5th percentile female and 50th percentile male crash dummies, 30 degree oblique tests into a rigid barrier using unbelted 50th percentile male dummies, and 40 percent offset frontal deformable barrier tests using belted 5th percentile female dummies. While Alternatives 1 and 2 both require a 0 to 48 kmph (0-30 mph) belted test for the 5th percentile female and 50th percentile male dummy, the primary difference between Alternatives 1 and 2 is their treatment of unbelted occupants. Alternative 1 would require an unbelted 32 to 40 kmph (20 to 25 mph) frontal rigid barrier test, while Alternative 2 would require an unbelted 32 to 48 kmph (20 to 30 mph) frontal rigid barrier test. Alternative 3 is the final rule. It is the same as Alternative 1 (an unbelted 32 to 40 kmph [20 to 25 mph] frontal rigid barrier test), but increases the speed of the belted test for the 50th percentile male dummy test to 0-56 kmph (0-35 mph). Chapter I provides the detail of the three alternative sets of high speed tests.

NHTSA is also upgrading the injury criteria applicable to the existing 50th percentile male dummy, and applying appropriate injury criteria to each of the new dummies in this rule. These criteria are used to assess the risk of injury. The new criteria will change the way head injuries are measured, include a measure of neck injury, and reduce the allowable chest deflection during the tests.

Technical Feasibility

The agency has tested three vehicles to most of the proposed tests. These are the Dodge Intrepid, the Toyota Tacoma, and the Saturn SL1. The Saturn passed all of the 30 mph rigid barrier tests, the static low risk deployment tests on the driver side, and the 35 mph belted test with the 50th percentile dummy. It did not meet the static low risk deployment tests on the passenger side. However, with the addition of a weight sensor, the agency believes the 1999 Saturn could pass the passenger side suppression tests. The Saturn performed better in these tests overall than the Intrepid or Tacoma. The Saturn SL1 has a soft crash pulse and it has a different air bag design than most vehicles with an unusual tether design in the center of the air bag. The agency believes that, at a minimum, different designs, more advanced sensors, and multi-stage inflators would be required in many vehicles to pass all of the tests considered in the three alternatives.

The agency also tested 11 other vehicles to understand how they would perform in different test conditions, most notably, in the high speed unbelted tests. These tests show that model year (MY) 1998-99 air bags generally meet our new injury criteria for unbelted 50th percentile male dummies in a 48 kmph (30 mph) unbelted test and for 5th percentile female dummies in a 32 kmph (25 mph) unbelted test. Five of twelve vehicles tested met our new injury criteria for 5th percentile female dummies in 48 kmph (30 mph) unbelted tests on the driver side and five of eleven met the new criteria on the passenger side. The data suggests that, at a minimum, design changes, such as recessing the air bag, improving fold patterns, and installing internal baffles in the air bag to assure safer deployment would be required for 50th male and 5th female dummies to simultaneously meet our injury criteria in 48 kmph (30 mph) belted and unbelted tests. The body of tests suggests that meeting the injury criteria for both the 50th percentile male and 5th percentile female in unbelted 48 kmph (30 mph) rigid barrier tests, while at the same time meeting the out-of-position tests, is a complex job. Adding pretensioners to belt systems may be needed by some vehicles to meet the 35 mph belted test with the 50th percentile male dummy.

It should be noted that there is significant complexity in air bag testing and technology that will be required by this final rule. We are requiring the use of a new test dummy (the 5th percentile female dummy) in high speed tests, adding a new test (offset belted), adding new neck injury criteria, and making existing injury criteria more stringent (chest deflection). We are also adding an entire new series of low-speed tests, which will require manufacturers to install air bag suppression systems or low risk deployment systems, or both. Simultaneously meeting the performance requirements of the low speed tests and the unbelted test speed will require the introduction of risk reduction technologies and increase the technical complexity in system design.

Benefits

The assessment provides analyses of the safety benefits from tests that reduce the risk of injury from air bags in low-speed crashes, as well as from tests that improve the overall effectiveness of air bags in high speed crashes. The agency estimates that in a fleet fully equipped with pre-model year (MY) 1998 air bags, there would be 46 drivers, 18 infants, 105 children, and 18 adult passengers (187 occupants in total) at risk of being killed by air bags annually because they were out of position when the air bag deployed in low speed [< 40 kmph (25 mph) delta-v] crashes. A variety of technologies would be required to prevent these deaths, including weight or presence sensors to suppress the air bag, multi-stage inflators, and low risk deployment air bags. Of the 187 potential at-risk fatalities, NHTSA estimates that suppression technologies could prevent up to 93 fatalities, low-risk air bags could prevent up to 154 fatalities, and multi-stage inflation systems could prevent up to 179 fatalities when combined with weight sensors used to suppress the air bag. Thus, more than 95 percent of the fatalities seen to date in low speed deployments could be eliminated by technologies used to meet the test requirements.

NHTSA also estimates that a fully air bag equipped fleet would result in serious to critical severity (MAIS 3-5) nonfatal injury caused by air bags to 38 drivers, 9 infants, 200 children, and 15 adult passengers that would be out of position in low speed crashes. Of these 262 serious but nonfatal injuries, suppression technologies could prevent 151 injuries, low-risk air bags could prevent 191 injuries, and multi-stage inflation systems could prevent up to 252 injuries when combined with a weight sensor. Thus, more than 95 percent of the air bag caused injuries in low speed deployments could be eliminated by technologies used to meet the test requirements.

There is some question about the reliability of suppression and low risk deployment countermeasures and further development of these countermeasures is necessary. To the extent that these systems are not as reliable as assumed, children and small adults would continue to be at risk. Even if suppression and low risk deployment technologies are completely reliable, there will remain some out-of-position individuals subject to the full force of the air bag under certain circumstances. The risks to out-of-position individuals could be greater with an air bag designed to provide a 30 mph unbelted performance compared to an air bag designed to provide 25 mph unbelted performance.

In addition to minimizing the risk to out of position occupants, this rulemaking seeks to improve occupant protection provided by air bags for both belted and unbelted occupants of all sizes, with new tests and new injury criteria. Among the tests this analysis examines are three different high speed tests that would improve the performance of air bags. These include the 25 mph offset test for belted 5th percentile female dummies, the 30 mph rigid barrier test for both belted and unbelted 5th percentile female dummies, and the 35 mph rigid barrier test for belted 50th percentile male dummies. A variety of technologies could be used to comply with these tests including modified air bag fold patterns, improved inflators, added sensors, multi-stage inflators, and pretensioners. Air bag systems designed to comply with the 25 mph offset test would, over the lifetime of one model year's production, save 20-28 more lives and prevent 134-262 more nonfatal injuries than the pre-MY 1998 baseline vehicles. Systems designed to the 30 mph tests with the 5th percentile female dummy would save 23 more lives (4 belted and 19 unbelted) and prevent 184 more nonfatal injuries (43 belted and 141 unbelted). Systems that meet the 35 mph rigid barrier test with the belted 50th percentile male dummies would save from 0-4 more lives and prevent 256 to 486 more nonfatal injuries.

Table E-1 summarizes the estimated benefits from the low speed tests and from the high speed tests, excluding the difference for the unbelted high speed tests (25 mph or 30 mph).

Table E-1
Estimated Range of Benefits for Low Speed Tests,
Offset Tests, 5th Female and 50th Male Belted Tests, and New Injury Criteria

Alternative	Fatalities Reduced	Injuries Reduced
#1	117 - 211	328 - 557
#2	136 - 230	469 - 698
#3	117 - 215	584 - 1,043

The most contentious issue of this rulemaking is whether the unbelted tests should be set at 40 kmph (25 mph) or 48 kmph (30 mph). Estimates of the relative impact of the unbelted high speed tests are subject to a degree of uncertainty for several reasons, not the least of which is the fact that no vehicles were ever subject to a 25 mph unbelted standard. We cannot estimate the most likely difference between setting the unbelted tests at the two different levels, because it depends on how the manufacturers would meet the alternative performance requirements.

In the preamble to the final rule, we discuss in detail our reasons for believing that it is unlikely that vehicle manufacturers will significantly depower their air bags compared to the MY 1998-2000 fleet. Vehicle manufacturers have not depowered their air bags so much that they minimally comply with the sled test. Crash tests and field experience to date with vehicles certified to the sled test have indicated that there has not been a loss of frontal crash protection compared to pre-MY 1998 vehicles. If, as we expect, the manufacturers keep the same level of power as they currently have in MY 1998-2000, even with a 25 mph unbelted test requirement, then the difference in actual benefits between the two test speeds would be small or even eliminated.

At the same time, we cannot rule out the possibility that air bags will be significantly depowered. To account for this possibility, we calculated a "worst case" scenario comparing the benefits at the minimum performance requirements of each speed. We derived point estimates using two different methods and different sets of assumptions. We estimate that vehicles designed with 30 mph air bags could provide 229 or 394 more lives saved than vehicles designed with minimally compliant 25 mph air bags. However, we also estimate that 30 mph air bags could result in an additional 1,345 serious injuries[1] compared to vehicles designed with 25 mph air bags. These point estimates do not necessarily define the full range of possible outcomes due to uncertainty regarding both data and assumptions under each method.

The total benefits from tests that reduce the risk of injury and tests that improve occupant protection are combined in Table E-2 for the three alternatives. The range of benefits provided in Table E-2 assume the worst case difference between vehicles designed to meet the 25 mph unbelted test and vehicles designed to meet the 30 mph unbelted test at the low end of the range and assume there is no difference in benefits between the 25 mph unbelted test and the 30 mph unbelted test at the high end of the range. The high end of the range is based upon the assumption that manufacturers might make no changes in their current vehicles even with a 25 mph unbelted standard.

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[1] The less aggressive single-stage air bag that can be designed to a 25 mph unbelted test can result in fewer air bag caused injuries at low speeds than an air bag designed to a 30 mph unbelted test. Thus, single-stage air bags designed to a 30 mph unbelted test can prevent more fatalities, while single-stage air bags designed to a 25 mph unbelted test can prevent more injuries. Multi-stage air bags are assumed to provide the same level of benefits during the first stage, whether the second stage is designed for a 25 mph unbelted test or a 30 mph unbelted test.

The agency estimates that the 30 mph generic sled test is roughly equivalent to a 22 mph rigid barrier perpendicular (0 degree) crash. During the depowering rulemaking, we looked at the relative safety consequences of an air bag designed to just meet the performance requirements associated with a 30 mph generic sled test. The agency estimated the fatality impacts of designing a vehicle to minimally meet the performance requirements imposed by the current 30 mph generic sled test and compared these to the fatality impacts of designing a vehicle to just meet the 25 mph unbelted rigid barrier test. Assuming there is no impact on air bag size, air bags designed to the 25 mph unbelted rigid barrier test could save 64 to 144 more lives than air bags designed to the generic sled test (assumed to be 22 mph). Assuming air bags designed to the generic sled test would be reduced in size and provide no benefit in partial frontal impacts, since the 25 mph unbelted rigid barrier test includes an up to 30 degree oblique test for the 50th percentile dummy while the generic sled test has no angular component, 282 to 308 more lives (this range includes the 64 to 144 estimates mentioned earlier) could be saved by air bags designed to the 25 mph unbelted rigid barrier test with the oblique test than lives saved by air bags designed to just comply with the generic sled test.

Costs

Potential compliance costs for the Final Rule vary considerably and are dependent upon the method chosen by manufacturers to comply. Methods such as modified fold patterns and inflator adjustments can be accomplished for little or no cost, given enough leadtime. More sophisticated solutions such as proximity sensors can increase costs significantly. Dynamic presence sensors (the technology assumed for the high end costs of Option 1) are not available at this point in time. They have not been refined to the point that they are in use in vehicles and are not required by tests in any Alternative. However, they have the potential to provide more benefits on the passenger side than weight sensors or low risk air bags. Dynamic presence sensors could be used by manufacturers to meet the test requirements in the future. As such, the cost and benefits of these systems have been estimated. The range of potential costs for the compliance scenarios examined in this analysis is $21-$128 per vehicle (1997 dollars). This amounts to a total potential annual cost of up to $2 billion, based on 15.5 million vehicle sales per year.

Property Damage Savings

Compliance methods that involve the use of suppression technology have the potential to produce significant property damage cost savings because they prevent air bags from deploying unnecessarily. This saves repair costs to replace the passenger side air bag, and frequently to replace windshields damaged by the air bag deployment. Property damage savings from these requirements could total up to $85 over the lifetime of an average vehicle. This amounts to a potential cost savings of $1.3 billion.

Net Cost Per Fatality Prevented

Estimates were made of the net costs per equivalent fatality prevented. The low end of the range for both Alternative1 and Alternative 3 Option 1 scenarios produced no positive net benefits. This reflects the conflicting impacts on fatalities and injuries that result from air bags designed to just meet an unbelted 25 mph test. Lives are not saved in high speed crashes, but nonfatal injuries are prevented in lower speed crashes. The positive impact on nonfatal injuries almost totally offsets the negative impact on fatalities. For the high end of the Option 2 scenarios, property damage savings have the potential to offset all, or nearly all of the cost of meeting this final rule.

In these cases, both net costs and safety impacts are positive so there is no cost per equivalent fatality, just cost savings and safety benefits.

Conclusions

Table E-2 summarizes the costs and benefits of the different Alternatives.

Table E-2
Summary of Costs and Benefits

	Cost Per Vehicle	Total Costs (Billions)	Lifetime Property Damage Savings Per-Vehicle	Total Property Damage Savings (Billions)	Net Consumer Costs (Savings) (Billions)
Alternative 1, Option 1	$21-$124	$0.32 - $1.93	$12-$85	$0.19-$1.31	$0.13-$0.61
Alternative 1, Option 2	$24-$65	$0.37-$1.01	$12-$85	$0.19-$1.31	$0.18-($0.30)
Alternative 2, Option 1	$21-$125	$0.32-$1.93	$12-$85	$0.19-$1.31	$0.13-$0.62
Alternative 2, Option 2	$24-$66	$0.37-$1.02	$12-$85	$0.19-$1.31	$0.18-($0.29)
Alternative 3, Option 1	$23-$128	$0.36-$1.98	$12-$85	$0.19-$1.31	$0.17-$0.67
Alternative 3, Option 2	$27-$68	$0.41-$1.06	$12-$85	$0.19-$1.31	$0.22-($0.25)
	Annual Fatalities Prevented	Annual Nonfatal Injuries Prevented	Total Equivalent Fatalities Prevented	Net Cost Per Fatality Saved (Millions)	
Alternative 1, Option 1	-233 to 211	1,710-1,902	-24 to 316	NS - $1.9M	
Alternative 1, Option 2	-202 to 209	1,756-1,891	6 to 313	$30.9M - NC	
Alternative 2, Option 1	162 to 230	498-2,059	168 to 342	$0.8M - $1.8M	
Alternative 2, Option 2	204 to 228	861-2,048	231 to 339	$0.8M - NC	
Alternative 3, Option 1	-233 to 215	1,966-2,388	-5 to 356	NS - $1.9M	
Alternative 3, Option 2	-202 to 213	2,012-2,377	25 to 353	$9.0M - NC	

NS = Negative safety benefits
NC = No cost, or a net cost savings

Alternative 1 includes: 20-25 mph unbelted test, 0-30 mph belted test, 0-25 mph offset belted test
Alternative 2 includes: 20-30 mph unbelted test, 0-30 mph belted test, 0-25 mph offset belted test
Alternative 3 includes: 20-25 mph unbelted test, 0-30 mph belted test for 5th female, 0-35 mph belted test for 50th male, 0-25 mph offset belted test
Option 1 includes, passengers up to 6 years old suppression, driver low risk air bag
Option 2 includes, infant suppression, passenger low risk air bag, driver low risk air bag

I. INTRODUCTION

This assessment accompanies a final rule to upgrade the agency's standard to improve occupant protection provided by air bags. While current air bags have been shown to be highly effective in reducing overall fatalities and injuries, sometimes their deployment has resulted in fatalities to out-of-position occupants, especially children. The final rule seeks both to improve air bag performance and to minimize the risks from air bags.

The final rule provides options to manufacturers to account for the differing kinds of technological solutions that may be used to address this problem, e.g., technologies that enable air bags to deploy in a manner so they do not result in serious injuries or which suppress air bag deployment in the presence of infants or out-of-position occupants.

<u>September 1998, Notice of Proposed Rulemaking</u>:

On September 18, 1998, NHTSA published in the **Federal Register** (63 FR 49958) a notice of proposed rulemaking (NPRM) to upgrade Federal Motor Vehicle Safety Standard (FMVSS) No. 208, <u>Occupant Crash Protection</u>, to require advanced air bags.

The NPRM proposed to add a new set of requirements to prevent air bags from causing injuries and to expand the existing set of requirements intended to ensure that air bags cushion and protect occupants in frontal crashes. There would be several new performance requirements to ensure that the advanced air bags do not pose unreasonable risks to out-of-position occupants.

The proposal included options for complying with those requirements so that vehicle manufacturers would be free to choose from a variety of effective technological solutions and to develop new ones if they so desire. With this flexibility, they could use technologies that control air bag deployment so deploying air bags do not cause serious injuries or that prevent air bag deployment if children or out-of-position occupants are present.

To ensure that the new air bags are designed to reduce the chance of causing injury to a broad array of occupants, NHTSA proposed test requirements using dummies representing 12-month-old, 3-year-old and 6-year-old children, 5th percentile adult females, and 50th percentile adult males. Many of the proposed test procedures were new, and comments were specifically requested with respect to their suitability for measuring the performance of the various advanced systems under development.

NHTSA proposed requirements to ensure that the new air bags are designed to cushion and protect a broader array of belted and unbelted occupants, including teenagers and small women. The standard's current dynamic crash test requirements specify the use of 50th percentile adult male dummies only. NHTSA also proposed to specify use of 5th percentile adult female dummies for these tests. The weight and size of these dummies are representative of not only small women, but also many teenagers.

NHTSA also proposed to add a deformable barrier crash test. This proposed new crash test requirement was intended to ensure that air bag systems are designed so that the air bag deploys earlier in crashes with softer crash pulses, before normally seated occupants, including small-statured ones, move too close to the air bag. NHTSA proposed to use 5th percentile adult female dummies in this test.

NHTSA also proposed to phase out the unbelted sled test option as vehicle crash test requirements for advanced air bags are phased in. Although it was believed that the sled test option has been a useful temporary measure to ensure that the vehicle manufacturers could quickly depower all of their air bags and to help ensure that some protection would continue to be provided, NHTSA did not consider sled testing to be an adequate long-term means of assessing the extent of occupant protection that a vehicle and its air bag will afford occupants in the real world.

Finally, NHTSA proposed new and/or upgraded injury criteria for each of the existing and proposed new test requirements.

November 1999, Supplemental Notice of Proposed Rulemaking:

On November 5, 1999, NHTSA published in the Federal Register (64 FR 60556) a supplemental notice of proposed rulemaking (SNPRM) to upgrade FMVSS 208 to require advanced air bags (Docket No. 1999-6407; Number 1)[1]. Three support documents were published at the same time.

[1] To read the docket go to http://dms.dot.gov, click on "search", type in four-digit docket number "6407", click on "search".

These were:

1) "Preliminary Economic Assessment, SNPRM, FMVSS No. 208, Advanced Air Bags" (Docket 1999-6407, Number 2)

2) "Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems II" (Docket 1999-6407, Number 5) and

3) "Updated Review of Potential Test Procedures for FMVSS No. 208"(Docket 1999-6407, Number 6)

NHTSA has analyzed the public comments and also conducted some additional testing. Specific comments are addressed as appropriate throughout this analysis. Many are addressed in Appendix B.

In the supplemental notice of proposed rulemaking (SNPRM) the agency modified its proposal based on information gathered and research conducted. The agency again proposed tests to minimize the risks to infants, children, and other occupants from injuries and deaths caused by air bags (see Figure I-1). The structure of these tests have remained essentially the same for the final rule.

The agency also proposed two alternatives for dynamic frontal crash tests. One of these included a return to an unrestrained rigid barrier test (in the speed range of 18 mph to a high end between 25 and 30 mph). Also under consideration was an unbelted 18 to 25 mph unbelted frontal rigid barrier test coupled with an increase in the belted test from the current up to 30 mph test, to a 35 mph test. The belted up to 35 mph test could have a different effective date than the effective date for the unbelted 25 mph test.

The agency proposed other requirements to the standard's dynamic frontal crash test requirements to enhance protection for a wider range of occupants. The current dynamic crash test requirements specify use of 50th percentile male dummies. The agency proposed those same requirements also be met using 5th percentile female dummies. In addition, the agency proposed to add a new dynamic offset deformable barrier crash test. This test is intended to ensure that air bags deploy sufficiently early in a crash, before normally seated occupants move too close to the air bag. This up to 25 mph test into an offset deformable barrier using belted 5th percentile female dummies was initially proposed in the NPRM.

The second alternative included a second offset deformable barrier test which must be passed at any speed between 22-35 mph using both 5th female and 50th male unbelted dummies. This test could result in improved vehicle structural integrity. The agency also proposed specifications for the deformable barrier for this test.

The alternatives considered in this Final Economic Analysis

The agency has decided not to include the 22-35 mph offset deformable test using unbelted dummies in the final rule. This test had no support at all from commenters. Commenters had concerns about the variability of the test and concerns about how this test might force them into sensor designs that would result in more air bag deployments than desired. They also stated that the European barrier used in the offset test is not appropriate for testing larger sport-utility vehicles and light trucks.

This analysis examines three specific sets of groupings for the high speed tests. While the agency considered different alternative speeds and different effective dates being phased-in, this analysis examines only the eventual full implementation considered for this rulemaking, regardless of the effective dates. These are shown as Alternative 1 (see Figure I-2), Alternative 2 (see Figure I-3), and Alternative 3 (see Figure I-4). See the leadtime discussion in Chapter VII for the phase-in schedules considered and the eventual final rule dates chosen.

Alternative 1
High Speed Test Requirements

20 to 25 mph unbelted for 5th female	–	perpendicular only
20 to 25 mph unbelted for 50th male	–	perpendicular and +/- 30 degrees
0 to 30 mph belted for 5th female	–	perpendicular only
0 to 30 mph belted for 50th male	–	perpendicular only
0 to 25 mph belted with 5th female	–	offset on driver side

Alternative 2
High Speed Test Requirements

20 to 30 mph unbelted for 5th female	–	perpendicular only
20 to 30 mph unbelted for 50th male	–	perpendicular and +/- 30 degrees
0 to 30 mph belted for 5th female	–	perpendicular only
0 to 30 mph belted for 50th male	–	perpendicular only
0 to 25 mph belted with 5th female	–	offset on driver side

Alternative 3
High Speed Test Requirements

20 to 25 mph unbelted for 5^{th} female	–	perpendicular only
20 to 25 mph unbelted for 50^{th} male	–	perpendicular and +/- 30 degrees
0 to 30 mph belted for 5^{th} female	–	perpendicular only
0 to 35 mph belted for 50^{th} male	–	perpendicular only
0 to 25 mph belted with 5^{th} female	–	offset on driver side

The final rule also establishes new injury criteria for the existing 50th percentile male dummy, as well as injury criteria for the new dummies (12-month old infant, 3-year old child, 6-year old child, and 5th percentile female dummy). The criteria include a few modifications from those proposed in the SNPRM. A detailed discussion of these criteria is provided within the analysis in Chapter III.

Figure I-1

Test Requirements to Minimize the Risk to Infants
Children and Other Occupants from Injuries
And Deaths Caused by Air Bags

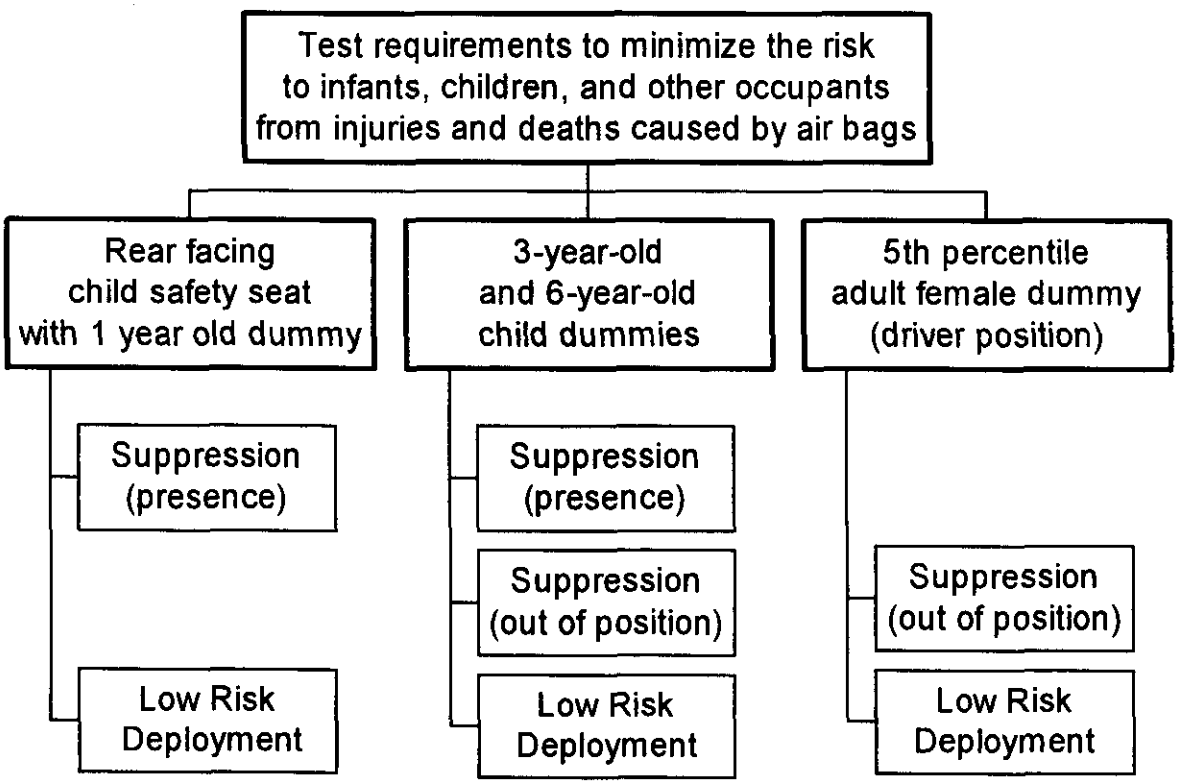


Figure I-2

High Speed Test Requirements to Preserve and Improve Occupant Protection

Alternative 1

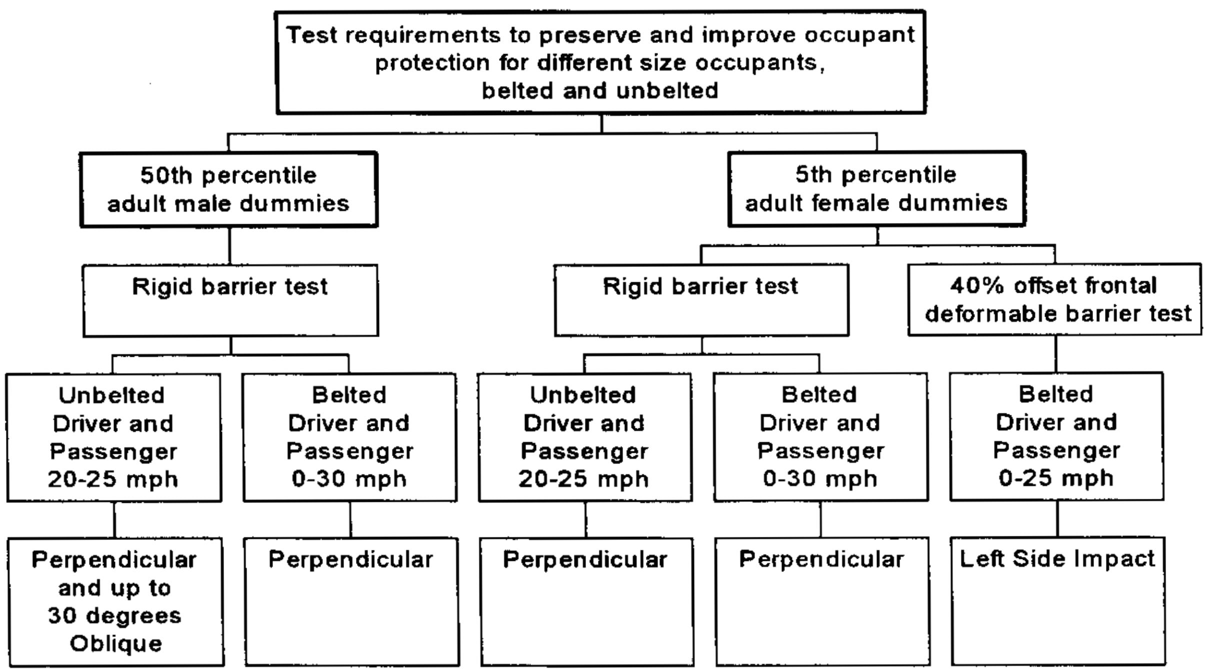


Figure I-3

High Speed Test Requirements to Preserve and Improve Occupant Protection

Alternative 2

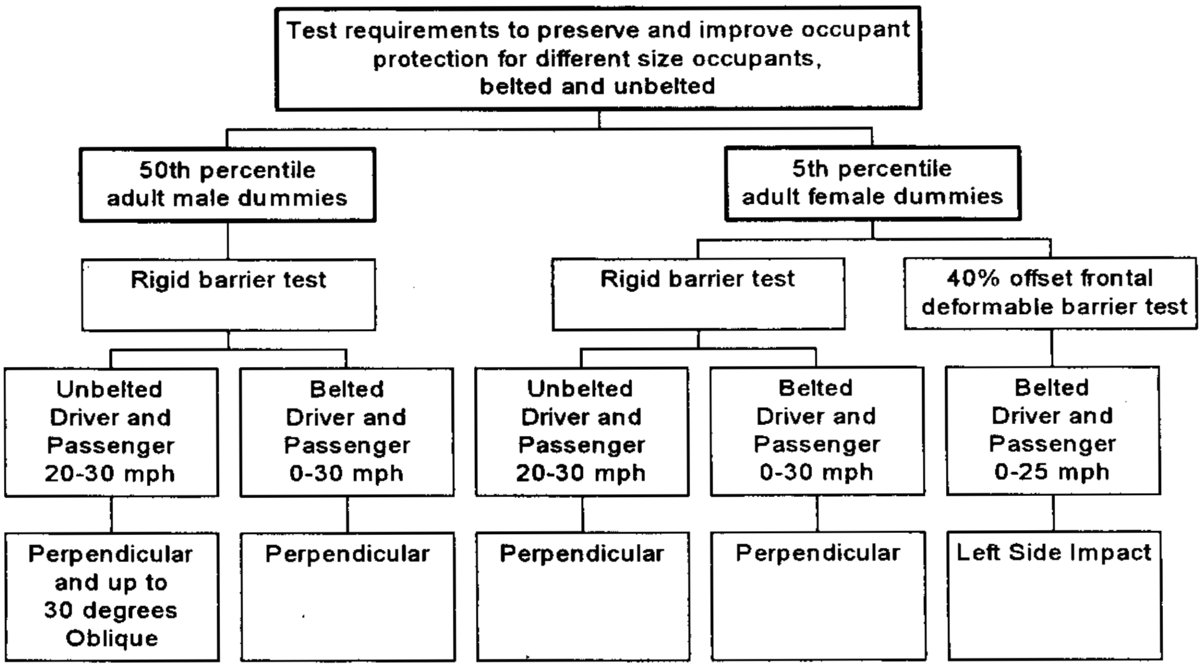
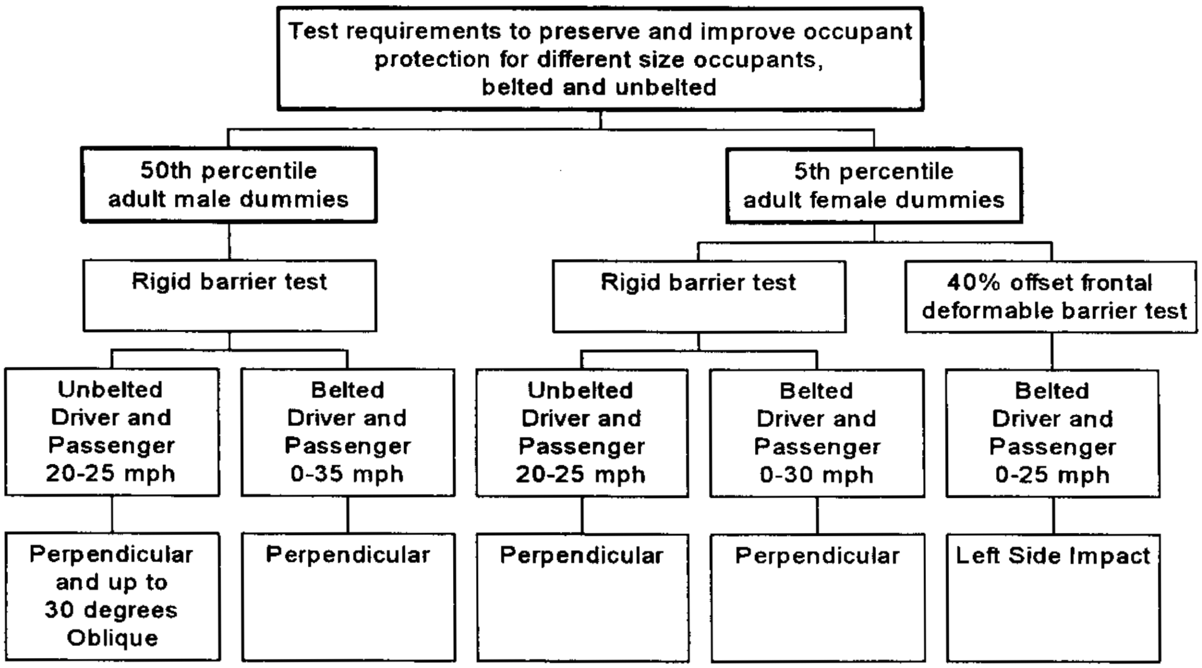


Figure I-4

High Speed Test Requirements to Preserve and Improve Occupant Protection

Alternative 3



II. TARGET POPULATION AND SAFETY CONCERNS

Advanced air bags have the potential to improve the benefits of air bag systems and to reduce air bag induced fatalities and serious injuries. This chapter estimates the size of the potential target population that would benefit from advanced air bags. Fatalities and injuries are discussed in separate sections.

A. Fatalities

Fatalities reported here were derived from NHTSA's 1997 Fatality Analysis Reporting System (FARS). In 1997, there were a total of 18,136 drivers and right front passengers killed in frontal crashes (see Table II-1) which accounted for about 63 percent of fatalities to these occupants. Of the 18,136 fatalities, 14,004 (77 percent) were drivers and 4,132 were right front-seated passengers. The majority (68 percent) of these fatalities were unrestrained occupants[1].

Table II-2 shows these fatalities disaggregrated by impact speeds and belt use. Note that fatal frontal crashes in FARS are categorized by initial or principal point of impacts (IMPACT1 or IMPACT2). Occupants are considered to be in frontal crashes if their vehicles had an area of damage in a 10-2 o'clock direction. Distribution by crash impact speeds was derived from

[1]. The restraint use distribution was based on the 1993 to 1997 National Automotive Sampling System (NASS) Crashworthiness Data System (CDS), so that this table would be consistent with Table II-2. Table II-2 provides a distribution of fatalities by delta v. Delta v is only available in NASS-CDS.

Table II-1
1997 Driver and Right Front Passenger Fatalities

All Impact Modes	Drivers	Right Front Passengers	Total
Passenger Cars	14,843	4,987	19,830
Restrained	5,552	1,895	7,447
Unrestrained	9,291	3,092	12,383
Light Trucks/Vans	6,937	1,969	8,906
Restrained	2,583	755	3,338
Unrestrained	4,354	1,214	5,568
Total	21,780	6,956	28,736
Restrained	8,135	2,650	10,785
Unrestrained	13,645	4,306	17,951
Frontal Impacts*			
Passenger Cars	9,489	2,992	12,481
Restrained	3,036	957	3,993
Unrestrained	6,453	2,035	8,488
Light Trucks/Vans	4,515	1,140	5,655
Restrained	1,445	365	1,810
Unrestrained	3,070	775	3,845
Total	14,004	4,132	18,136
Restrained	4,481	1,322	5,803
Unrestrained	9,523	2,810	12,333

Source: NHTSA 1997 Fatality Analysis Reporting System (FARS), 1993-97 Crashworthiness Data System (CDS)
* Frontal crashes are defined as initial or principal impact force from 10-2 o'clock direction.

the 1993 to 1997 NASS CDS. Because of variations in data elements describing crash characteristics, it is not possible to establish a one-to-one association between FARS and CDS; hence frontal crashes are defined somewhat differently for these two databases. Frontal crashes in the NASS CDS are defined by their principal direction of force (DOF1), their general area of damage (GAD1), and the primary specific horizontal location (SHL1) as either:

GAD1='F' (front),

or

GAD1 = 'L' (left side) or GAD1 = 'R' (right side), and

SHL1 = 'F' (front), and

DOF1=10, 30, 50, 70, 90, 11, 31, 51, 71, 91, 12, 32, 52, 72, 92, 1, 21, 41, 61, 81, 2, 33, 42, 62, 82

or

GAD1 = 'L' (left side) or GAD1 = 'R' (right side), and

SHL1 ^= 'F' (front), and

DOF1=11, 31, 51, 71, 91, 12, 32, 52, 72, 92, 1, 21, 41, 61, 81

Table II-2
Fatalities In Frontal Impacts By Crash Severity

Actual Fatalities (1997)	Crash Severity (Speed in MPH) 0-25	26-30	31-35	36+	Total
Drivers	4,792	2,168	1,804	5,240	14,004
Restrained	1,721	493	674	1,593	4,481
Unrestrained	3,071	1,675	1,130	3,647	9,523
Passengers	1,414	639	532	1,547	4,132
Restrained	507	145	199	471	1,322
Unrestrained	907	494	333	1,076	2,810
Total	6,206	2,807	2,336	6,787	18,136
Restrained	2,228	638	873	2,064	5,803
Unrestrained	3,978	2,169	1,463	4,723	12,333

Source: NHTSA 1993-1997 CDS and 1997 FARS.
Note: Fatalities by crash speeds and belt use were derived from 1993-1997 CDS and adjusted to 1997 FARS level.

The agency has estimated that air bags have saved 5,303 lives cumulatively from 1987 through March 1, 2000. In calendar year 1997, about 36 percent of the on-road passenger cars and 28 percent of light trucks/vans were equipped with driver side air bags, and 22 percent of passenger cars and 17 percent of light trucks/vans were equipped with passenger side air bags. Air bags saved an estimated 842 lives in 1997. If one assumes that all passenger vehicles (cars, utility vehicles, light trucks, and vans) had been equipped with air bags, they would have saved an estimated 3,253 lives annually. In total, there would have been 18,978 (18,136 + 842) potential fatalities associated with frontal impacts if no vehicles had air bags in 1997. Potential fatalities are defined as people in frontal crashes that died plus those that would have been fatally injured in the absence of air bags.

Table II-3 shows, by several crash impact speed levels, the potential fatalities, lives that would have been saved, and the remaining fatalities if all vehicles in the fleet were equipped with pre-98 air bag systems. Advanced air bags have the potential to reduce the remaining fatalities. Belt use in Table II-3 is assumed to be the same as found in 1993-1997 CDS fatalities at 32 percent.

As shown in Table II-3, an entire fleet of pre-MY 1998 air bags would save an estimated 3,253 lives annually. Air bags are thus an important source of occupant protection in current passenger vehicles. However, air bags may have adverse effects on occupants who are too close to the air bags when they deploy. Of particular concern are children. As of January 1, 2000, NHTSA's Special Crash Investigation (SCI) Program has identified a total of 169 cases (142 confirmed and 27 still under investigation) of < 25 mph Δv in which the deployment of an air bag resulted in fatal injuries to an occupant between 1990 and 1998. Of these 169 fatalities, 17 were infants in rear-facing child safety seats (RFCSS), 79 were children aged one to twelve years old, 63 were drivers, and 10 were adult passengers. These cases were then projected to an annual basis under the assumption that all passenger vehicles were equipped with pre-MY 1998 air bags by multiplying the actual number of incidents by an adjustment factor (f) that adjusts the vehicle fleet to a fleet in which all vehicles have air bags. By assuming that air bag-induced fatalities are proportional to the percentage of the fleet with air bags, the adjustment factor for each year is the ratio of the number of vehicles in operation to the number with air bags, i.e., f=1/r where r is the percentage of the fleet with air bags. The corresponding mathematical formula is:

Table II-3
Estimated Lives Saved and Fatalities Remaining in Frontal Crashes
Assuming the Whole Fleet of Passenger Vehicles Had Air Bags

Potential Fatalities With No Air Bags	Crash Severity (Speed in MPH)				Total
	0-25	26-30	31-35	36+	
Drivers	5,035	2,278	1,895	5,507	14,715
Restrained	1,797	514	705	1,664	4,680
Unrestrained	3,238	1,764	1,190	3,843	10,035
Passengers	1,459	659	549	1,596	4,263
Restrained	522	150	204	483	1,359
Unrestrained	937	509	345	1,113	2,904
Total	6,494	2,937	2,444	7,103	18,978
Restrained	2,319	664	909	2,147	6,039
Unrestrained	4,175	2,273	1,535	4,956	12,939
Estimated Lives Saved with Full Fleet of Air Bags					
Drivers	1,133	535	425	381	2,474
Restrained	323	93	127	91	634
Unrestrained	810	442	298	290	1,840
Passengers	328	154	123	174	779
Restrained	94	27	37	49	207
Unrestrained	234	127	86	125	572
Total	1,461	689	548	555	3,253
Restrained	417	120	164	140	841
Unrestrained	1,044	569	384	415	2,412
Fatalities Remaining with Full Fleet of Air Bags					
Drivers	3,902	1,743	1,470	5,126	12,241
Restrained	1,474	421	578	1,573	4,046
Unrestrained	2,428	1,322	892	3,553	8,195
Passengers	1,131	505	426	1,422	3,484
Restrained	428	123	167	434	1,152
Unrestrained	703	382	259	988	2,332
Total	5,033	2,248	1,896	6,548	15,725
Restrained	1,902	544	745	2,007	5,198
Unrestrained	3,131	1,704	1,151	4,541	10,527

Source: NHTSA 1993-1997 CDS and 1997 FARS.
Note: Fatalities by crash speeds were derived from 1993-1997 CDS and adjusted to 1997 FARS level.

$$Pd = Ad * f$$

where Pd = projected deaths

Ad = actual number of deaths from SCI cases

f = the ratio of the number of total vehicles to number of vehicles with air bags.

Table II-4 shows actual and projected fatalities by years. The actual fatalities, except calendar year 1998, were those fatalities caused by pre-MY 1998 air bags. For year 1998, fatalities caused by MY-1998 (redesigned) air bags were also included in the projection because many pre-MY 1998 air bags deployed at a greater force and thus would have killed the same occupants if the pre-MY 1998 air bags were installed in the vehicles.

If all passenger vehicles were equipped with air bags, for example in the year 1998 (using the above formula Pd=Ad*f), about 15 (4*1/0.272) infants in RFCSS, 77 (21*1/0.272) children, 11 (3*1/0.272) adult passengers, and 28 (11*1/0.394) drivers would have been killed by air bags (and otherwise probably would not have died if there had been no air bag).

Table II-4
Projected At-Risk Fatalities by Years

	Portion of Fleet with Air Bags		SCI Cases as of 08/01/99				Projected Annual Number			
Year	Driver	Passenger	RFCSS	Children 1-12 Years Old	Adult Passengers	Drivers	RFCSS	Children 1-12 Years Old	Adult Passengers	Drivers
90	0.018	0.001	0	0	0	1	0	0	0	56
91	0.027	0.001	0	0	0	4	0	0	0	148
92	0.050	0.003	0	0	0	3	0	0	0	60
93	0.083	0.008	0	1	0	4	0	125	0	48
94	0.128	0.026	0	5	0	7	0	192	0	55
95	0.188	0.065	3	6	0	5	46	92	0	27
96	0.258	0.126	6	19	2	7	48	151	16	27
97	0.328	0.201	4	27	5	21	20	134	25	64
98	0.394	0.272	4	21	3	11	15	77	11	28
98[1]	0.068[2]	0.068	0	2	1	1	See further discussion			

1. This row provides information for 1998 vehicle models with redesigned air bags in calender year 1998. These fatalities are included in the 1998 numbers above.
2. The number is derived by assuming 1998 model vehicles accounted for 7.84 percent of the fleet in operation and 87 percent of these new vehicles were equipped with redesigned air bags, i.e., 0.068=0.0784*0.87.

In late 1996, the agency started a much broader public awareness program on the potential adverse effect of air bags. In addition, the agency required 1998 new vehicles to have air bag warning labels. Increasing public awareness of the air bag occupant safety issue reduced the air bag risk to rear-facing infants and children. As shown in Table II-4, the number of air bag induced fatalities gradually reduced, especially from 1997 to 1998. To take the effectiveness of the public awareness into account and to reduce year by year fluctuation, this analysis uses the weighted average of 1997 and 1998 projected deaths to estimate an annualized baseline fatal population for the at-risk groups. These projected deaths were weighted by the number of on-road operational vehicles in the fleet. There were about 194,653,000 and 198,401,000 passenger vehicles on the road in 1997 and 1998, respectively. The annualized deaths can be written as following:

Annualized Deaths = $(194{,}653{,}000 * Pd_{97} + 198{,}401{,}000 * Pd_{98})/(194{,}653{,}000+198{,}401{,}000)$

where Pd_{97} = projected deaths in 1997

Pd_{98} = projected deaths in 1998.

Because more vehicles were on the road in 1998 than in 1997, the annualized projection thus gave a slightly greater weight to 1998 cases. In total, as shown in Table II-5, there would be approximately18 infants in RFCSS, 105 children aged 1-12, 18 adult passengers, and 46 drivers[2] killed by air bags if all vehicles in the fleet were equipped with pre-MY 1998 air bags. For comparison purpose, the projected annual deaths for MY 1998 air bags are presented here. Note, the projected numbers based on the performance of MY 1998 air bags were derived from analysis of limited SCI data. Following is a detailed description of the analysis.

Table II-5
Estimated Annual At-Risk Fatalities With A Full Fleet of Air Bags
by Air Bag Types

At-Risk Group	Annual Deaths	
	Pre-MY 1998 Air Bags*	MY 1998 Air Bags**
Drivers	46	15
Adult Passengers	18	5
Children 1 to 12 Years Old	105	35
Infants in RFCSS	18	10
Total	187	65

*Annual deaths were projected using 1997 and 1998 fatal cases only.
** Based on judgment and analysis of minimal data.

[2] The figures in the table are slightly different from the estimates in the "Preliminary Economic Assessment, FMVSS No.208, Advanced Air Bags" August 1998, NHTSA, because this analysis uses 1997 FARS and 1993-1997 CDS crash data. Also, this analysis used a different projection approach to estimate the annual at-risk population. Finally, the number killed by air bags was projected using later data from the Special Crash Investigation program, up to January 1, 2000.

An analysis of Special Crash Investigation (SCI) Fatalities by Model Year and Investigation Date was undertaken to determine how well the redesigned air bags were performing, based on the minimal data available. Table II-6 shows these data, which compare SCI Cases, including those cases not on the official list yet in ( ). This analysis compares what was known to the SCI team two years and three months (27 months) after the start of the new model year and compares MY 1996 vehicles to MY 1997 vehicles to MY 1998 vehicles over the same length of time (vehicle months on the road). No adjustments are made to this table for increased seat belt use over this period of time. The results indicate that there are still fatalities occurring to out-of-position occupants with the redesigned air bags, but fatalities appeared to have been reduced from 19 in MY 96 and 20 in MY 97, to seven in MY 98 vehicles (two of these were in vehicles with air bags that were not redesigned). Table II-7 shows these data compared to Polk registrations (discussed further at length later in this analysis). The average of MY 96 and MY 97 data is a fatality rate of 1.43. Compared to this, the fatality rate for MY 1998 of 0.48, is 33.6 percent. Part of this reduction comes from redesigned air bags and part of it comes from changes in behavior, including increased overall belt use, putting children in the rear seat, and sitting further away from the steering wheel. One way to get an initial estimate of what part of the reduction in SCI fatality rate is due to redesigned air bags as opposed to changes in behavior is to examine the difference in fatality rates between Table II-7 and its endnote (MY 1998 having a fatality rate that is .35 of the fatality rate for MY 96 and 97 over their first 27 months) and Table II-8 (MY 1998 having a fatality rate that is .56 of the fatality rate over their last 27 months). Comparing these two rates would indicate that about 2/3 of the benefit (1-.56=.44; 1-.35=.65; .44/.65=.677) seen to date is from the redesign of the air bags and 1/3 of the benefit is from changes in behavior. Initial data indicate that redesigned air bags are making good progress towards reducing the out-of-position problem.

The data are not robust enough to have any confidence about how well redesigned air bags are working for the four individual categories of out-of-position occupants (rear facing infants, forward facing children, adult passengers, and drivers). However, the potential difference is significant enough that the agency will perform a sensitivity analysis, assuming redesigned air bags reduce the potential target population to 33.6 percent of its estimated total based on pre-MY 1998 models. For Table II-5, a distribution for the at-risk groups is provided based on the roughly one-third fatality rate. With no infant fatalities in rear facing child safety seats, the estimate of 10 is based on engineering judgment comparing the "aggressiveness" of pre-MY 1998 air bags to MY-1998 air bags, in general.

Table II-6
Special Crash Investigation Cases

MY and (dates investigated)	Rear Facing Infant Fatals	Forward Facing Child Fatals	Adult Passenger Fatals	Driver Fatals	Total Fatals
MY 1999 redesigned (15 months)	0	2	0	0	2
MY 1998 redesigned (10/1/97 to 1/1/00) (27 mos.)	0	2	(1)	1 + 1 fetus	4 + 1 fetus
MY 1998 not redesigned (10/1/97 to 1/1/00) (27 mos.)	0	(1)	0	1	2
MY 1997 (10/1/96 to 1/1/99) (27 mos.)	2	6 + (4) = 10	1 + (3) = 4	2 + (2) = 4	20
MY 1996 (10/1/95 to 1/1/98) (27 mos.)	1	9 + (3) = 12	0	5 + (1) = 6	19

* Cases under investigation, but not on official list yet.

Table II-7*
SCI Cases per Million Registered Vehicles

	SCI Fatalities Over the First 27 Months of the MY Life	Total Registrations from Polk (millions of vehicles)	SCI Fatalities per Million Vehicles Registered
MY 1996 (10/01/95 to 11/01/97)	19	13.103	1.45
MY 1997 (10/01/96 to 11/01/98)	20	14.174	1.41
MY 1998 (10/01/97 to 11/01/99)	7	14.569 (estimated)	0.48

* See endnote at the end of this chapter.

Table II-8 presents the similar statistics from the analysis described above but for fatalities that occurred over the last 27 months (10/01/97 to 1/01/00). The comparison indicates fatalities are a little lower over the last 27 month period. The MYs 96-97 averaged 19.5 fatalities (see Table II-7) over the first 27 months and 13.5 fatalities over the last 27 months. Rather than simply use registration data, the number of vehicle months on the road over the 27 month period was calculated taking into account registrations, vehicle miles traveled by age, and the monthly introduction of sales for new models. Thus, the MY 98 vehicles first year sales from October 1997 to October 1998 result in the MY 98 vehicles having less time on the road during this year than the MY 97 or 96 vehicles whose sales are essentially completed before the start of the 27 month period starting October 1997. The data still show that redesigned air bags perform better for out-of-position occupants.

Table II-8
SCI Cases per Million Vehicle Months

	SCI Fatalities Over the Last 27 Months (10/01/97-1/01/00)	Millions of Vehicle Months Over the Last 27 Months (10/01/97 - 1/01/00)	SCI Fatalities per Million Vehicle Months
MY 1996	12	24.678	0.49
MY 1997	15	29.851	0.50
MY 1998	7	25.093 (estimated)	0.28

Tables II-7 and II-8 showed that redesigned air bags perform better for out-of-position occupants. However, the reduction in out-of-position occupant fatalities were not impacted by redesigned air bags alone. Parents' behavior change also was a contributing factor. Table II-9 lists the percentages of children that sat in the back seat of vehicles with or without right front seat air bags by calendar year. These statistics were based on all child passengers age 0-12 in passenger cars, survivors plus fatalities, in FARS from 1995 through mid-1999.

Table II-9
Percent of Child Occupants in Back Seat

Calendar Year	Age 0-12	Age 0	Age 1-5	Age 6-10	Age 11-12
In Cars with Dual Air Bags					
1995	67	71	68	67	64
1996	69	71	71	67	66
1997	74	89	79	70	65
1998	78	84	84	75	60
1999	77	90	87	73	53
In MY 1985-96 Cars without Dual Air Bags					
1995	69	61	73	68	60
1996	70	65	73	69	62
1997	69	67	75	64	64
1998	72	72	78	70	61
1999	70	74	77	62	63

These statistics show that (1) the percent of infants and toddlers riding in the back seat of cars with dual air bags has increased substantially since 1996 - from about 70 to about 90 percent. (2) There are also moderate increases in back-seat occupancy by 1-10 year old children in cars with dual air bags - and 0-5 year old children in cars without dual air bags. (3) Overall, from 1997 to 1998, children (age 0 to 12) riding in the back seat had increased about 4 percentage points for cars with dual air bags and 3 percentage points for cars without dual air bags.

Another analysis to assess the impact of the MY 1998-2000 redesigned air bags on baseline population estimation is to examine the FARS for 1998 and the first 6 months of 1999. Air bag vehicles were broken up into redesigned air bags and those not redesigned using data provided by the manufacturers to NHTSA. Only MY 1995 to MY 2000 were analyzed to reduce the potential for an age effect, anti-lock brake effect and the effect of differences in the fleet brought about by increasing light truck and van sales. The question we were trying to answer is whether the frontal fatality rate increased with the decrease in power in redesigned air bags. Fatalities in frontal crashes to front outboard occupants were compared to fatalities in other crash modes. Testing results at 30 and 35 mph showed no difference for belted occupants and a slight difference for unbelted occupants between redesigned and pre-MY 98 vehicles. Most vehicles met the 30 mph unbelted test anyway. We would expect that no difference could be found without substantially more data. No statistically significant difference was found.

The percent of fatalities that were frontal are:

57.3 % for redesigned air bags (1,051 in frontals and 782 in non-frontals)
57.7 % for not redesigned air bags (3,684 in frontals and 2,699 in non-frontals)

This results in a risk ratio of 0.985 [(1,051/782)/(3,684/2,699)], or a 1.5 percent reduction in frontal fatalities for redesigned air bags. This is not a statistically significant difference.

These pre-MY 1998 air bags, would save 3,253 lives annually, however, 187 occupants would be killed by the air bags. Thus, the net estimated lives saved would be 3,066 (3,253 - 187). Table II-10 summarizes these estimates in detail. It is important to note that the projections were based on all identified (confirmed and unconfirmed) cases. However, there are 5 unconfirmed cases in 1997 and 14 unconfirmed cases in 1998, therefore, the projected annualized at-risk population could be smaller. Equally important is the fact that all the estimates are based on the assumption that, in the future years, there are no changes in occupant demographics, driver/passenger behavior, belt use, child restraint use, or the percent of children sitting in the front seat. As public education programs are more successful in creating better awareness of occupant safety issues, and as auto manufacturers voluntarily phase in improved air bags, the potential negative safety impacts of air bags would be further reduced.

Table II-10
Estimated Full Fleet Impacts of Pre-MY 1998 Air Bags on Fatalities

	Saved	Killed	Net Impacts
Drivers	2,474	46	2,428
Passengers	779	141	638
Adults	779	18	761
Children	0*	105	-105
RFCSS	0	18	-18
Total	3,253	187	3,066

* Potentially there are benefits from air bags for correctly positioned children in high severity impacts. Sled test data do show a reduction in injury measures for correctly positioned child dummies with air bags compared to belted child dummies in 30 mph impacts. This does not appear to be the case for infants in rear facing child safety seats. All RFCSS tests have indicated an increased probability of head injury with air bags. Statistical analyses have shown negative effectiveness of air bags for children. This implies that the negative impacts of air bags for children at low speeds are overwhelming the benefits, if any, for children at high speeds. It is impossible to prove that an air bag saved a life in a particular high speed crash, since about 50 percent of unbelted occupants survive (with injuries) in crashes with a change in velocity (delta V) of 30 to 40 mph. Until there are enough data available to do a statistical analysis of the effectiveness of air bags for children at different speeds, the agency cannot estimate the benefits of air bags for children under the age of 12.

B. Injuries

The injury population assessment uses two data sources: the 1993-1997 CDS and the 1997 General Estimates System (GES)[3]. GES is the main database used by the agency to produce national statistics on nonfatal crashes in the U.S. However, GES is a sample taken directly from police-reported crashes and does not provide in-depth investigations of injury profiles and crash

[3] General Estimates System Coding Manual 1997.

configurations as does CDS. This analysis uses GES to estimate the size of injury populations and CDS to describe crash characteristics such as MAIS injury severity and delta v for crash severity.

CDS contains data on all passenger vehicle crashes where at least one passenger vehicle was towed, while GES is a sample of all police-reported crashes not limited to passenger vehicle tow-away crashes. Therefore, injury counts derived from CDS were adjusted only to the GES CDS-equivalent level. As with FARS, this adjustment cannot establish a one-to-one association between GES CDS-equivalent crashes and CDS crashes. CDS equivalent frontal crashes in GES are defined by Hotdeck imputed initial point of impact (IMPACT_H) and vehicle damage area (DAM_AREA) as:

IMPACT_H=1 (front), 11 (front right corner), 12 (front left corner)

<u>or</u>

IMAPCT_H=2 (right side) or 3 (left side), and
DAM_AREA has included 1 (front).

In 1997, there were 280,881 driver and right front passenger MAIS 2-5 and 1,650,175 MAIS 1 non-fatal injuries associated with frontal crashes. MAIS 1-5[4] injuries reported in Table II-11 and Table II-12 were adjusted to 1997 GES CDS-equivalent injury levels.

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[4]. Maximum Abbreviated Injury Scale, 1-Minor Injury, 2-Moderate Injury, 3-Serious Injury, 4-Severe Injury, 5-Critical Injury. Only one injury with the most severity is counted per occupants.

Table II-11
1997 Drivers and Right Front Passengers With MAIS 2-5 Injuries

All Impact Modes	Drivers	Right Front Passengers	Total
Passenger Cars	258,058	77,282	335,340
Restrained	141,546	42,285	183,831
Unrestrained	116,512	34,997	151,509
Light Trucks/Vans	72,591	21,573	94,164
Restrained	40,159	11,910	52,069
Unrestrained	32,432	9,663	42,095
Total	330,649	98,855	429,504
Restrained	181,705	54,195	235,900
Unrestrained	148,944	44,660	193,604
Frontal Impacts			
Passenger Cars	165,607	47,862	213,469
Restrained	94,396	27,281	121,677
Unrestrained	71,211	20,581	91,792
Light Trucks/Vans	52,297	15,115	67,412
Restrained	29,809	8,616	38,425
Unrestrained	22,488	6,499	28,987
Total	217,904	62,977	280,881
Restrained	124,205	35,897	160,102
Unrestrained	93,699	27,080	120,779

Source: NHTSA 1997 National Automotive Sampling System - General Estimated System (NASS-GES) and - 1993-1997 Crashworthiness Data System (CDS)
Note: MAIS 2-5 injuries were derived from 1993-1997 CDS and adjusted to 1997 GES-CDS equivalent level.

Table II-12
1997 Drivers and Right Front Passengers With MAIS 1 Injuries

All Impact Modes	**Drivers**	**Right Front Passengers**	**Total**
Passenger Cars	1,554,059	466,118	2,020,177
Restrained	1,153,790	346,700	1,500,490
Unrestrained	400,269	119,418	519,687
Light Trucks/Vans	434,808	129,391	564,199
Restrained	320,715	95,598	416,313
Unrestrained	114,093	33,793	147,886
Total	1,988,867	595,509	2,584,376
Restrained	1,474,505	442,298	1,916,803
Unrestrained	514,362	153,211	667,573
Frontal Impacts			
Passenger Cars	972,941	281,192	1,254,133
Restrained	700,518	202,458	902,976
Unrestrained	272,423	78,734	351,157
Light Trucks/Vans	307,245	88,797	396,042
Restrained	221,216	63,934	285,150
Unrestrained	86,029	24,863	110,892
Total	1,280,186	369,989	1,650,175
Restrained	921,734	266,392	1,188,126
Unrestrained	358,452	103,597	462,049

Source: NHTSA 1997 National Automotive Sampling System - General Estimated System (NASS-GES) and - 1993-1997 Crashworthiness Data System (CDS)
Note: MAIS 1 injuries were derived from 1993-1997 CDS and adjusted to 1997 GES-CDS equivalent level.

Air bags proved to be 10 percent[5] (not statistically significant) effective in reducing MAIS 2-5 injuries. Annually, air bags would reduce about 29,070 MAIS 2-5 injuries. Table II-13 shows three types of MAIS 2-5 injury estimates in frontal crashes by person role (driver, passenger) and crash impact speeds. These estimates are: number of MAIS 2-5 injuries with no air bags (potential MAIS 2-5 injuries), injuries reduced, and number of remaining MAIS 2-5 injuries if the whole fleet had air bags. There would be a total of 261,635 MAIS 2-5 injuries remaining annually if all vehicles had pre-MY 1998 air bags. Advanced air bags would have the potential to further reduce these remaining injuries. Note that the distribution of MAIS 2-5 injuries by person role, crash impact speeds (delta v), and restrained use were derived from 1993-1997 CDS statistics. Of the total shown, MAIS 2 injuries were 66.2 percent, MAIS 3 were 27.5 percent, MAIS 4 were 4.7 percent, and MAIS 5 were 1.6 percent. Belt use in Table II-13 is the same level found in 1993-1997 CDS at 57 percent for AIS 2-5 injuries.

A table like Table II-12 was not derived for MAIS 1 injuries since the agency believed the effectiveness of air bags for AIS 1 injuries is minimal. Many occupants have a red face from "bag slap" which is considered an AIS 1 injury. Thus, the effectiveness of reducing overall AIS 1 injuries with pre-MY 1998 air bag is believed to be minimal.

[5] The Fourth Report to Congress, Effectiveness of Occupant Protection Systems and Their Use, May 1999.

Table II-13
Estimated MAIS 2-5 Injuries Remaining
Assuming the Whole Fleet of Passenger Vehicles Had Air Bags

Potential Injuries With No Air Bags	Crash Severity (Speed in MPH)				Total
	0-25	26-30	31-35	36+	
Drivers	183,401	23,829	8,313	10,558	226,101
Restrained	112,103	8,773	4,173	4,043	129,092
Unrestrained	71,298	15,056	4,140	6,515	97,009
Passengers	52,339	6,801	2,372	3,092	64,604
Restrained	31,992	2,504	1,190	1,177	36,863
Unrestrained	20,347	4,297	1,182	1,915	27,741
Total	235,740	30,630	10,685	13,650	290,705
Restrained	144,095	11,277	5,363	5,220	165,955
Unrestrained	91,645	19,353	5,322	8,430	124,750
Estimated MAIS 2-5 Injuries Reduced with Full Fleet of Air Bags					
Drivers	18,340	2,383	831	1,056	22,610
Restrained	11,210	877	417	404	12,908
Unrestrained	7,130	1,506	414	652	9,702
Passengers	5,234	680	237	309	6,460
Restrained	3,199	250	119	118	3,686
Unrestrained	2,035	430	118	191	2,774
Total	23,574	3,063	1,068	1,365	29,070
Restrained	14,409	1,127	536	522	16,594
Unrestrained	9,165	1,936	532	843	12,476
MAIS 2-5 Injuries Remaining with Full Fleet of Air Bags					
Drivers	165,061	21,446	7,482	9,502	203,491
Restrained	100,893	7,896	3,756	3,639	116,184
Unrestrained	64,168	13,550	3,726	5,863	87,307
Passengers	47,105	6,121	2,135	2,783	58,144
Restrained	28,793	2,254	1,071	1,059	33,177
Unrestrained	18,312	3,867	1,064	1,724	24,967
Total	212,166	27,567	9,617	12,285	261,635
Restrained	129,686	10,150	4,827	4,698	149,361
Unrestrained	82,480	17,417	4,790	7,587	112,274

Source: NHTSA 1993-1997 NASS CDS and 1997 GES.
Note: Injuries by crash speeds were derived from 1993-1997 CDS and adjusted to 1997 GES CDS-equivalent level.

In addition to air bag induced fatalities, SCI also identified some cases where children and adults who sit too close to air bags were seriously injured when air bags deployed in low speed impacts. But these SCI cases are by no means comprehensive, and thus might underestimate air bag induced serious injuries if used as the basis to project annual at-risk serious injuries (MAIS 3-5). Instead, the at-risk fatalities were used as the basis. For each MAIS 3-5 injury level, the estimate of annualized at-risk fatalities is multiplied by the ratio (adjustment factors) of injuries to fatalities. The adjustment factors and the ratio of air bag induced injuries to fatalities were derived from 1993-1998 CDS nonweighted cases and SCI cases. The 1998 CDS data were used here to include more air bag induced cases. Because of very small sample size for infants and children, the nonweighted cases were used to derive the ratios of injuries to fatalities. Table II-14 shows that there are an estimated annual total of 9 infants in RFCSS, 200 children, 15 adult passengers, and 38 drivers seriously injured by air bags.

Table II-14
Projected Annualized At-Risk MAIS 3-5 Injuries

	Projected Annual Number			
Year	**RFCSS**	**Children 1-12 Years Old**	**Adult Passengers**	**Drivers**
Baseline (at-risk fatalities)	18	105	18	46
Adjustment Factors				
MAIS 5	0.5	0.8	0.1	0.1
MAIS 4	0.0	0.8	0.1	0.1
MAIS 3	0.0	0.3	0.6	0.6
Projected Injuries				
MAIS 5	9	84	2	5
MAIS 4	0	84	2	5
MAIS 3	0	32	11	28
Total MAIS 3-5	9	200	15	38

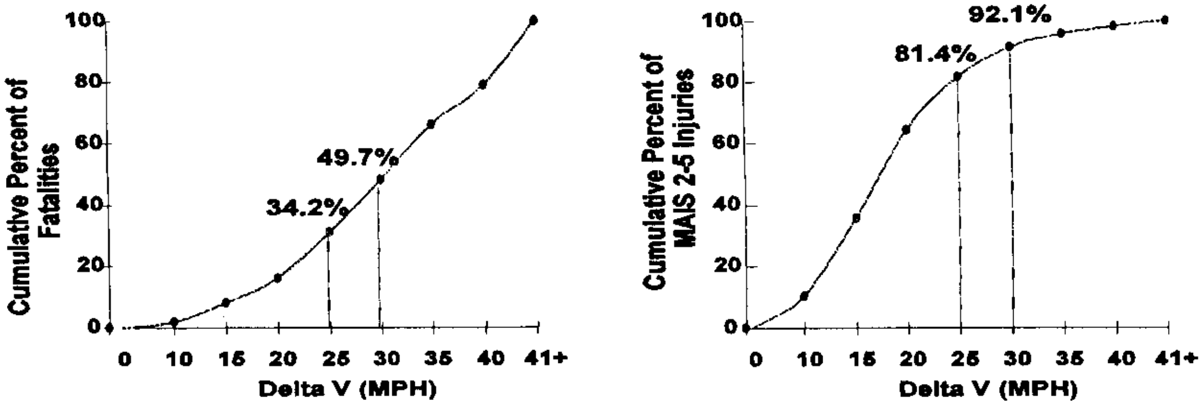
Source: SCI cases as of January 1, 2000; 1993-1998 CDS
Note: Baseline is the projected annualized at-risk fatalities.

The following Tables II-15 to II-17 show fatalities and different MAIS injury levels by crash severity (delta v) in frontal crashes. Broken out further, Table II-15 presents these statistics for all front-outboard occupants, belted and unbelted combined; Table II-16 presents statistics for unbelted front-outboard occupants; while Table II-17 presents statistics for belted front-outboard occupants. These tables serve as additional background information to make a necessary adjustment of the overall target population and to analyze benefits for these tests. Figure II-1 graphically depicts the cumulative percentages of fatalities and MAIS 2-5 injuries by crash impact speeds (delta v).

Table II-15
Front-Outboard Occupant Fatalities and MAIS 2-5 Injuries
in Frontal Crashes by Crash Impact Speeds

Delta V (MPH)	Fatal %	Fatal Cumulative %	MAIS 4-5 %	MAIS 4-5 Cumulative %	MAIS 3-5 %	MAIS 3-5 Cumulative %	MAIS 2-5 %	MAIS 2-5 Cumulative %
0-10	2.0	2.0	4.3	4.3	3.9	3.9	11.4	11.4
11	1.0	3.0	0.7	5.0	6.1	10.0	5.7	17.1
12	1.9	4.9	1.2	6.2	7.6	17.6	5.6	22.7
13	0.4	5.3	3.3	9.5	1.6	19.2	3.4	26.1
14	2.5	7.8	4.5	14.0	7.2	26.4	7.7	33.8
15	1.7	9.5	0.7	14.7	4.4	30.8	3.5	37.3
16	1.8	11.3	2.7	17.4	5.5	36.3	5.8	43.1
17	0.9	12.2	2.5	19.9	8.9	45.2	11.7	54.8
18	0.3	12.5	2.0	21.9	1.7	46.9	3.6	58.4
19	2.6	15.1	3.0	24.9	2.9	49.8	4.5	62.9
20	0.9	16.0	1.9	26.8	2.5	52.3	2.0	64.9
21-25	18.2	34.2	22.7	49.5	19.3	71.6	16.5	81.4
26-30	15.5	49.7	18.9	68.4	14.3	85.9	10.7	92.1
31-35	12.9	62.6	7.0	75.4	5.8	91.7	3.9	96.0
36-40	13.5	76.1	16.1	91.5	4.7	96.4	2.2	98.2
41+	23.9	100.0	8.5	100.0	3.6	100.0	1.8	100.0

Source:1993-1997 CDS.



Note: Fatalities and MAIS 2-5 injuries with unknown crash impact speeds were excluded in the analysis.

Figure II-1. Percent of Front-Outboard Fatalities/MAIS 2-5 Injuries in Frontal Crashes by Crash Impact Speeds (Delta V)

Table II-16
Front-Outboard Occupant Unbelted Fatalities and MAIS 2-5 Injuries in Frontal Crashes by Crash Impact Speeds

Delta V (MPH)	Fatal %	Fatal Cumulative %	MAIS 4-5 %	MAIS 4-5 Cumulative %	MAIS 3-5 %	MAIS 3-5 Cumulative %	MAIS 2-5 %	MAIS 2-5 Cumulative %
0-10	2.8	2.8	5.8	5.8	5.6	5.6	9.9	9.9
11	1.2	4.0	1.0	6.8	1.7	7.3	3.4	13.3
12	1.4	5.4	1.3	8.1	1.8	9.1	3.0	16.3
13	0.4	5.8	3.4	11.5	1.5	10.6	3.6	19.9
14	2.9	8.7	4.4	15.9	12.0	22.6	8.2	28.1
15	0.7	9.4	0.6	16.5	1.4	24.0	1.9	30.0
16	1.3	10.7	3.2	19.7	4.7	28.7	4.0	34.0
17	0.5	11.2	2.2	21.9	3.9	32.6	10.0	44.0
18	0.3	11.5	2.0	23.9	1.4	34.0	1.6	45.6
19	3.3	14.8	2.0	25.9	2.8	36.8	4.1	49.7
20	1.3	16.1	1.0	26.9	1.7	38.5	1.4	51.1
21-25	17.4	33.5	20.2	47.1	26.0	64.5	23.4	74.5
26-30	17.9	51.4	18.6	65.7	17.8	82.3	15.6	90.1
31-35	12.0	63.4	6.2	71.9	7.3	89.6	4.5	94.6
36-40	14.6	78.0	19.1	91.0	6.1	95.7	2.7	97.3
41+	22.0	100.0	9.0	100.0	4.3	100.0	2.7	100.0

Source:1993-1997 CDS.
Note: Fatalities and MAIS 2-5 injuries with unknown crash impact speeds were excluded in the analysis.

Table II-17
Front-Outboard Occupant Belted Fatalities and MAIS 2-5 Injuries
in Frontal Crashes by Crash Impact Speeds

Delta V (MPH)	Fatal %	Fatal Cumulative %	MAIS 4-5 %	MAIS 4-5 Cumulative %	MAIS 3-5 %	MAIS 3-5 Cumulative %	MAIS 2-5 %	MAIS 2-5 Cumulative %
0-10	0.6	0.6	1.1	1.1	2.1	2.1	12.6	12.6
11	0.0	0.6	0.0	1.1	10.7	12.8	7.5	20.1
12	3.2	3.8	1.1	2.2	13.7	26.5	7.4	27.5
13	0.5	4.3	3.0	5.2	1.6	28.1	3.2	30.7
14	1.9	6.2	4.7	9.9	2.3	30.4	7.4	38.1
15	4.4	10.6	0.7	10.6	7.6	38.0	4.7	42.8
16	3.2	13.8	1.4	12.0	6.2	44.2	7.3	50.1
17	1.8	15.6	3.3	15.3	14.2	58.4	13.1	63.2
18	0.6	16.2	2.0	17.3	1.9	60.3	5.3	68.5
19	1.4	17.6	5.2	22.5	2.9	63.2	4.9	73.4
20	0.0	17.6	4.1	26.6	3.4	66.6	2.5	75.9
21-25	20.8	38.4	29.2	55.8	12.7	79.3	11.1	87.0
26-30	11.0	49.4	19.2	75.0	10.6	89.9	6.8	93.8
31-35	15.0	64.4	9.0	84.0	4.2	94.1	3.4	97.2
36-40	13.2	77.6	8.6	92.6	3.1	97.2	1.8	99.0
41+	22.4	100.0	7.4	100.0	2.8	100.0	1.0	100.0

Source:1993-1997 CDS.
Note: Fatalities and MAIS 2-5 injuries with unknown crash impact speeds were excluded in the analysis.

Endnote for Table II-7,

A small analysis was performed to examine the potential impact of the increase in belt use between 1996 and 1998 on the apparent change in fatality rates for redesigned MY 1998 air bag vehicles. Results from the National Occupant Protection Use Survey (NOPUS) show that the observed average overall safety belt use in front seat outboard passenger cars and light trucks was 61.3 percent in 1996 and 68.9 percent in 1998. Thus, safety belt use increased during the period. The estimates use the average effectiveness of safety belts for passenger cars and light trucks of about 51 percent (45 percent for passenger cars and 60 percent for light trucks). It is estimated that instead of the 19 fatalities that occurred over the first 27 months of the MY 1996 vehicles shown in Table II-7 with 61.3 percent belt use, that there would have been 18 fatalities if belt use had been 68.9 percent [19/(1-0.51*0.613) = 27.64; 27.64*0.51*0.689 = 9.71; 27.64-9.71 = 18]. The SCI fatalities per million registered MY 1996 vehicles using 18 fatalities instead of 19 would be 1.37 instead of 1.45.

The same calculation for 1997, assuming average belt use in 1997 midway between 1996 and 1998 of 65.1 percent resulted in 19 fatalities and the fatality rate at 1.34 for MY 1997 vehicles. Thus the average SCI fatality rate for MY's 1996/97 would be 1.36 [(1.37+1.34)/2]. Comparing this to MY 1998 rate of 0.48 results in 35 percent (0.48/1.36) rather than the previous estimate of 33.6 percent (0.48/1.43), still roughly one-third as used in the analysis for Table II-5.

III. INJURY CRITERIA

This section contains a description of the Injury Criteria and Injury Criteria Performance Limits (ICPL) mandated by the final rule on advanced frontal air bags. NHTSA is requiring separate ICPLs for each dummy size. This section describes how the dummy head, neck, chest and femur responses measured by the dummies relate to human tolerance/injury risk potential and the associated probability of injury. NHTSA is requiring ICPLs for head injury criterion (HIC), neck injury criterion (Nij), chest acceleration (chest g's) and chest deflection for each dummy size in addition to femur axial loads for the adult dummies.

Based on an analysis of the docket comments (99-6407), NHTSA is mandating; (1) the computation of HIC (maximum) be based on a 15 milliseconds (ms) time interval (compared to 36 ms in today's FMVSS 208) and (2) the application of new HIC threshold ICPLs for each dummy size. The final rule promulgates a new neck injury criteria (Nij) formulation employing further revised critical intercept values (compared to the SNPRM) to account for In-Position (tensed neck muscles) and Out-of-Position (untensed neck muscles) as well as new independent peak limits for neck tension and compression. The new peak limits on neck tension and compression adjust the shape of the "Kite"shaped boundary for Nij to a "Hexagonal"shaped boundary.[1] The same neck injury risk curves employed in the SNPRM benefit/cost analysis apply to the subject final rule analysis, despite these adjustments. The ICPL of 1.0 proposed in

[1] The "Kite" shape is based on the computation of Nij for which the measured values are dependent e.g., occur at the same point in time. The independent peak limits creating the "Hexagon" shape, however, are independent of time.

the SNPRM for Nij is being adopted for the final rule. With the exception of the Nij revised critical intercept values and new peak limits on neck tension and compression, the final rule requires the same HIC_{15ms}, chest acceleration, chest deflection and femur load ICPLs as proposed in the SNPRM.

The Combined Thoracic Index (CTI) is not being promulgated as an injury criteria in the final rule. However, the CTI concept of chest injury risk as employed in the SNPRM benefits/ costs analysis is used for the same purposes of analysis in the subject final rule in Chapter VI., Potential Benefits, to calculate chest injury risk reductions and subsequent benefits. For example, the Injury Assessment Reference Value (IARV) of 1.0 as applied to CTI in the benefits analysis section represents a 25 percent probability of an AIS 3+ human chest injury.[2]

In addition, this section includes a discussion of 95th percentile male dummy injury criteria and concomitant IARVs, as these are used for analysis purposes to assess the MY97 (baseline) vs. MY99 (redesigned) Buick Century and Chevy Venture sled buck air bag test series. Although not a promulgated dummy, revised critical intercept values for Nij and the new peak limits for neck tension and compression have been applied to this dummy size for analysis purposes.

[2] ICPLs were proposed in the SNPRM and became part of the final rule, whereas IARVs are used in conjunction with the injury criteria for analysis purposes only.

The 95th percentile dummy sled test responses are compared to the applicable injury criteria and appropriate IARVs.

NHTSA's National Transportation Biomechanics Research Center (NTBRC) has prepared a separate, supplemental biomechanics document that addresses the industry's comments, discusses each selected ICPL, the associated injury risk functions and the risk tolerance curves.[3]

A. Summary of NHTSA's ICPL Proposal

Head - After analysis of the comments to the SNPRM Docket 99-6407, the agency is requiring that the HIC (maximum) calculation time interval be changed from 36 ms to 15 ms. This results in a mandated HIC_{15} ICPL value of 700 for the 50th percentile male dummy. In addition, NHTSA is mandating a HIC_{15} of 700 for the 5th percentile female and 6-year-old dummies for the advanced frontal air bag final rule. Also, the agency is mandating HIC_{15}=570 and HIC_{15}=390 for the 3-year-old and 12-month-old infant (CRABI) dummies, respectively, which have been scaled from the 50th percentile dummy. Table III-1 shows the ICPLs requirements for each body region by dummy size.

[3] Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems -II, October, 1999, The original document was Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems, June, 1998. See Docket No. NHTSA-1998-4405-9. Supplement: Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems -II, March 2000,

Table III-1
Injury Criteria and Injury Criteria Performance Levels (ICPLs) for FMVSS No. 208 Final Rule by Anthropomorphic Dummy Size

208 Injury Criteria	Hybrid III Mid-Sized Male	Hybrid III Small Female	Hybrid III 6-Year-Old Child	Hybrid III 3-Year-Old Child	12-Month-Old Infant (CRABI)
Head Criteria (HIC_{15ms})	700	700	700	570	390
Neck Criteria (Nij)	1.0	1.0	1.0	1.0	1.0
<u>In-Position</u>					
Critical Intercept Values					
$F_{Z\ CRIT}$: Tension (N)	6806	4287			
$F_{Z\ CRIT}$: Compression (N)	-6160	-3880			
$M_{Y\ CRIT}$: Flexion (N-m)	310	155			
$M_{Y\ CRIT}$: Extension (N-m)	-135	-67			
Peak Limits					
Neck Tension (N)	4170	2620			
Neck Compression (N)	-4000	-2520			
<u>Out-of-Position (OOP)</u>					
Critical Intercept Values					
$F_{Z\ CRIT}$: Tension (N)		3880	2800	2120	1460
$F_{Z\ CRIT}$: Compression (N)		-3880	-2800	-2120	-1460
$M_{Y\ CRIT}$: Flexion (N-m)		155	93	68	43
$M_{Y\ CRIT}$: Extension (N-m)		-61	- 37	-27	-17
Peak Limits					
Neck Tension (N)		2070	1490	1130	780
Neck Compression (N)		-2520	-1820	-1380	-960
Thoracic Criteria					
A_C Critical Chest Acceler. (g's)	60	60	60	55	50
D_C Critical Chest Deflect (mm)	63 (2.5")	52 (2.0")	40 (1.6")	34 (1.4")	30 * (1.2")
Lower Extremity Criterion					
Femur Axial Loads (Kn)	10.0 **	6.8	N.A.	N.A.	N.A.

* The 12-month-old infant (CRABI) dummy is not currently capable of measuring chest deflection. ** The actual femur axial load ICPL is 10,008 Newtons, but this has been rounded to the nearest whole number in Table III-1. N.A. - not applicable. <u>In-position</u> critical intercept values and peak limits reflect tensed neck muscles, whereas <u>OOP</u> critical intercept values and peak limits reflect untensed neck muscles. This concept does not apply to the 12-month-old CRABI infant dummy.

Neck - NHTSA is mandating the same neck injury criterion (Nij) as proposed in the SNPRM, but with revised In-Position and Out-of-Position critical intercept values and new peak limits on neck tension and compression. The maximum allowable Nij = 1.0 applies regardless of dummy size. Nij is a linear combination of the normalized neck axial load (tension or compression) and normalized neck moment about the occipital condyle. The critical intercept values required to compute the normalized neck axial load (tension or compression) and normalized neck moment are different for each dummy size. The critical intercept values also produce the "Kite" shaped boundary for Nij less than or equal to 1.0 which has been revised in the final rule to a "Hexagonal" shaped boundary. The peak limits of neck tension and compression are used to truncate the upper and lower vertical apexes of the Kite shaped Nij boundary. Figures III-3 illustrates the hexagonal shaped Nij boundary for the in-position (tensed neck muscles) 50^{th} percentile male dummy. Figure III-4 illustrates the hexagonal shaped Nij boundary for In-Position (tensed neck muscles) and Out-of-Position (OOP) (untensed neck muscles) for the 5^{th} percentile female dummies. In order to pass the test, the Nij computation is less than 1.0 within the hexagonal boundary and equal to 1.0 on the boundary line. The OOP limits for neck tension and the neck extension moments are more stringent, compared to the in-position case, so as to reduce the risk of injury for the out-of-position occupant. [Note: The tensed and untensed neck muscle concept does not apply to the 12-month-old infant CRABI dummy.] (See Table III-1)

Chest - The chest acceleration and chest deflection ICPL values proposed in the SNPRM are required in the final rule for the 50th percentile male, 5th percentile female, 6-year-old child, 3-year-old child and 12-month-old infant dummies. The chest acceleration ICPL of 60 g's for the 50th percentile male dummy reflects about a 65 percent chance of an AIS-3+ injury as shown in Figure III-7. The chest g's limits for the other dummies are scaled for an equivalent level of risk. As described in the SNPRM documentation, the chest deflection threshold values for all the dummies were re-scaled to reflect that the 50th percentile male's maximum allowable chest deflection which was revised from 76 mm (NPRM) to 63 mm (3" to 2.5")(SNPRM and Final Rule). This essentially reduces the risk of an AIS-3+ chest injury from 47 percent (@ 76 mm) to 33 percent (@ 63 mm) as shown in Figure III-8. The maximum deflection thresholds for the other dummy sizes have been scaled from the 50 percentile male dummy. Test data shows this 17 percent reduction (76 mm to 63 mm) in the central chest deflection ICPL is practicable for many of the required full-scale crash test conditions, but may be more problematic for the required static OOP test conditions. [Note: 12-Month-Old Infant (CRABI) dummy does not currently have chest deflection measurement capability.] (See Table III-1)

Femurs - FMVSS 208 currently specifies a femur axial compressive load ICPL of 10 kN (2,250 lbs.) for the 50th percentile male dummy. In the SNPRM, NHTSA proposed a femur axial compression ICPL of 10 kN (2,250 lbs.) for the 50th percentile male dummy and 6.8 kN (1,530 lbs.) for the 5th percentile female femur, based on scaling of the cross-sectional area of the femur bone. These same values are mandated in the final rule. Femur loads are not included for the child dummies because the testing configurations specified in the SNPRM for the 6-year-old child dummy, namely OOP testing, do not impose substantial loading on the lower extremities. (See Table III-1)

The scaling methods used to derive the head, neck critical intercept values, chest deflection, chest acceleration, and femur ICPLs by dummy size are described in the previously referred to amended biomechanics report placed in the docket.

B. Injury Risk Curves

Head Injury Criterion (HIC_{15})

Based on available NCAP data, the HIC_{15} of 700 for the 50th percentile male dummy can be correlated to HIC_{36} of 1000 [$HIC_{15} = 0.7\ HIC_{36}$] and is designed to provide protection from head injury (e.g., skull fracture) for long duration events where there is no head contact with hard vehicle interior points. HIC was developed from short duration, hard rigid surface, cadaveric head drop data and was designed to minimize skull fracture/brain injury due to head contacts with interior compartment components. A short duration impact could include a direct driver head impact with the steering wheel rim/hub or a child's head contacting the unpadded face of the instrument panel. As shown in Table III-1, a maximum HIC_{15} of 700 is required for the 50^{th} percentile male dummy as well as the new 5th percentile female and the new 6-year-old child dummies. In addition, HIC_{15} = 570 is required for the new 3-year-old and HIC_{15} = 390 is required for the new 12-month-old infant (CRABI) dummy.[4]

Prasad and Mertz estimated head injury risk as a function of HIC and employed a 15 ms maximum time interval to calculate HIC.[5] The 15 ms time interval represented a hard rigid impact surface. NHTSA has used the 36 ms maximum time interval to compute HIC because it is believed to closely represent the softer vehicle interior head impact environment and indirectly provides neck tension protection by limiting Z-axis g's.[6] With the new neck criterion (Nij), HIC_{15} was reconsidered. The Prasad/ Mertz HIC values are shown in Table III-2.[7] NHTSA has expanded the Prasad/ Mertz curve to include other AIS levels (see Figure III-1). The lognormal curve values for HIC developed by Hertz of NHTSA are shown in Table III-3 and Figure III-2. The Hertz curves are representative of HIC_{15} as they were derived from short duration head drop data. See the supplemental biomechanics report for a further discussion of HIC_{15} vs HIC_{36} and the scaling factors used to derive ICPL values by dummy size.

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[4] Originally this dummy was named the Crash Research Air Bag Interaction dummy.

[5] Assessing the Safety Performance of Occupant Restraint Systems, Viano, D.C. and Arepally, S., Biomedical Science Department, GM Research Laboratories, General Motors Corporation, Warren, MI, SAE #902328. The Position of the U.S. Delegation to the ISO Working Group 6 on the Use of HIC in the Automotive Environment, P. Prasad of Ford Motor Company and H. J. Mertz of General Motors Corporation, SAE #851246 and Injury Risk Curves for Children and Adults in Front and Rear Collisions, H.J. Mertz, General Motors, P. Prasad, Ford Motor Co. and A.L. Irwin, General Motors, #973318.

[6] Final Regulatory Evaluation, FMVSS 208 - Front Seat Occupant Protection, Amendment to Provide a New Method for Calculating Head Injury Criterion (HIC), August 1986, Office of Regulatory Analysis, Plans and Policy, NHTSA/DOT.

[7] Final Regulatory Evaluation, Actions to Reduce Adverse Effects of Air Bags, FMVSS 208, DEPOWERING, February 1997, Office of Regulatory Analysis, Plans and Policy, NHTSA/DOT.

Table III-2
Expanded Prasad/Mertz Curves
Chance of Specific Injury Level for a Given HIC_{15} Level

HIC	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	FATAL	NO INJURY
50	0.3%	0.1%	0.1%	0.0%	0.0%	0.0%	99.5%
150	8.7%	2.8%	1.2%	0.3%	0.0%	0.0%	87.0%
250	21.8%	7.4%	2.9%	0.7%	0.1%	0.0%	67.2%
350	33.8%	13.7%	5.1%	1.3%	0.1%	0.0%	45.9%
450	40.1%	21.5%	8.1%	2.1%	0.2%	0.0%	28.1%
550	39.1%	29.7%	11.9%	3.2%	0.3%	0.0%	15.8%
650	33.0%	36.7%	16.7%	4.6%	0.5%	0.0%	8.5%
750	25.2%	40.8%	22.2%	6.6%	0.7%	0.0%	4.4%
850	17.8%	41.3%	28.2%	9.2%	1.2%	0.0%	2.3%
950	12.0%	38.5%	33.9%	12.6%	1.8%	0.1%	1.2%
1050	7.8%	33.5%	38.4%	16.8%	2.8%	0.2%	0.6%
1150	4.9%	27.6%	41.0%	21.7%	4.2%	0.3%	0.3%
1250	3.1%	21.7%	41.2%	27.0%	6.3%	0.5%	0.2%
1350	1.9%	16.5%	39.2%	32.1%	9.3%	0.8%	0.1%
1450	1.2%	12.2%	35.3%	36.3%	13.5%	1.5%	0.0%
1550	0.7%	8.8%	30.3%	38.7%	18.8%	2.6%	0.0%
1650	0.5%	6.3%	24.9%	38.7%	25.1%	4.6%	0.0%
1750	0.3%	4.4%	19.7%	36.1%	31.7%	7.8%	0.0%
1850	0.2%	3.1%	15.2%	31.3%	37.1%	13.1%	0.0%
1950	0.1%	2.2%	11.4%	25.4%	39.9%	21.0%	0.0%
2050	0.1%	1.5%	8.4%	19.4%	38.6%	32.0%	0.0%
2150	0.0%	1.0%	6.1%	14.0%	33.4%	45.4%	0.0%
2250	0.0%	0.7%	4.4%	9.7%	25.6%	59.5%	0.0%
2350	0.0%	0.5%	3.2%	6.5%	17.7%	72.2%	0.0%
2450	0.0%	0.3%	2.3%	4.2%	11.1%	82.1%	0.0%
2550	0.0%	0.2%	1.6%	2.7%	6.5%	89.0%	0.0%
2650	0.0%	0.2%	1.1%	1.7%	3.5%	93.4%	0.0%
2750	0.0%	0.1%	0.8%	1.1%	1.8%	96.2%	0.0%
2850	0.0%	0.1%	0.6%	0.6%	0.9%	97.8%	0.0%
2950	0.0%	0.1%	0.4%	0.4%	0.4%	98.7%	0.0%
3050	0.0%	0.0%	0.3%	0.2%	0.2%	99.3%	0.0%
3150	0.0%	0.0%	0.2%	0.1%	1.0%	99.6%	0.0%

Table III-3
Lognormal Curves Chance of Specific Injury Level for a Given HIC15 Level

HIC	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	FATAL	NO INJURY
50	7.6%	0.02%	0.00%	0.00%	0.00%	0.00%	92.38%
150	35.53%	1.01%	0.05%	0.00%	0.00%	0.00%	63.41%
250	52.06%	3.97%	0.44%	0.01%	0.01%	0.00%	43.52%
350	59.44%	8.01%	1.42%	0.06%	0.06%	0.04%	30.98%
450	61.55%	12.15%	2.96%	0.18%	0.19%	0.17%	22.80%
550	60.74%	15.84%	4.84%	0.40%	0.42%	0.51%	17.25%
650	58.37%	18.86%	6.81%	0.70%	0.73%	1.18%	13.36%
750	55.21%	21.16%	8.69%	1.06%	1.10%	2.24%	10.54%
850	51.72%	22.81%	10.34%	1.44%	1.50%	3.74%	8.45%
950	48.16%	23.88%	11.70%	1.81%	1.89%	5.70%	6.37%
1050	44.68%	24.47%	12.76%	2.15%	2.24%	8.08%	5.65%
1150	41.35%	24.67%	13.47%	2.44%	2.55%	10.83%	4.70%
1250	38.22%	24.57%	13.90%	2.68%	2.79%	13.89%	3.94%
1350	35.31%	24.24%	14.09%	2.86%	2.98%	17.19%	3.33%
1450	32.62%	23.73%	14.06%	2.98%	3.10%	20.68%	2.84%
1550	30.13%	23.08%	13.86%	3.04%	3.17%	24.28%	2.44%
1650	27.85%	22.35%	13.51%	3.06%	3.18%	27.95%	2.11%
1750	25.76%	21.55%	13.05%	3.03%	3.16%	31.62%	1.83%
1850	23.86%	20.71%	12.51%	2.97%	3.10%	35.27%	1.59%
1950	22.09%	19.85%	11.92%	2.88%	3.00%	38.86%	1.40%
2050	20.48%	18.99%	11.29%	2.77%	2.89%	42.35%	1.23%
2150	19.01%	18.13%	10.63%	2.65%	2.76%	45.74%	1.09%
2250	17.66%	17.29%	9.97%	2.51%	2.61%	49.01%	0.97%
2350	16.42%	16.46%	9.31%	2.36%	2.46%	52.14%	0.86%
2450	15.23%	15.66%	8.68%	2.21%	2.30%	55.12%	0.77%
2550	14.23%	14.89%	8.03%	2.06%	2.14%	57.96%	0.69%
2650	13.27%	14.14%	7.42%	1.91%	1.99%	60.65%	0.62%
2750	12.39%	13.43%	6.84%	1.76%	1.83%	63.20%	0.56%
2850	11.57%	12.75%	6.28%	1.62%	1.68%	65.60%	0.50%
2950	10.82%	12.10%	5.75%	1.48%	1.54%	67.86%	0.46%
3050	10.13%	11.47%	5.25%	1.35%	1.40%	69.98%	0.41%
3150	9.49%	10.89%	4.78%	1.22%	1.27%	71.98%	0.38%
3250	8.89%	10.33%	4.34%	1.10%	1.15%	73.84%	0.34%

Figure III-1
Prasad/Mertz Expanded
Head Injury Probability Curves

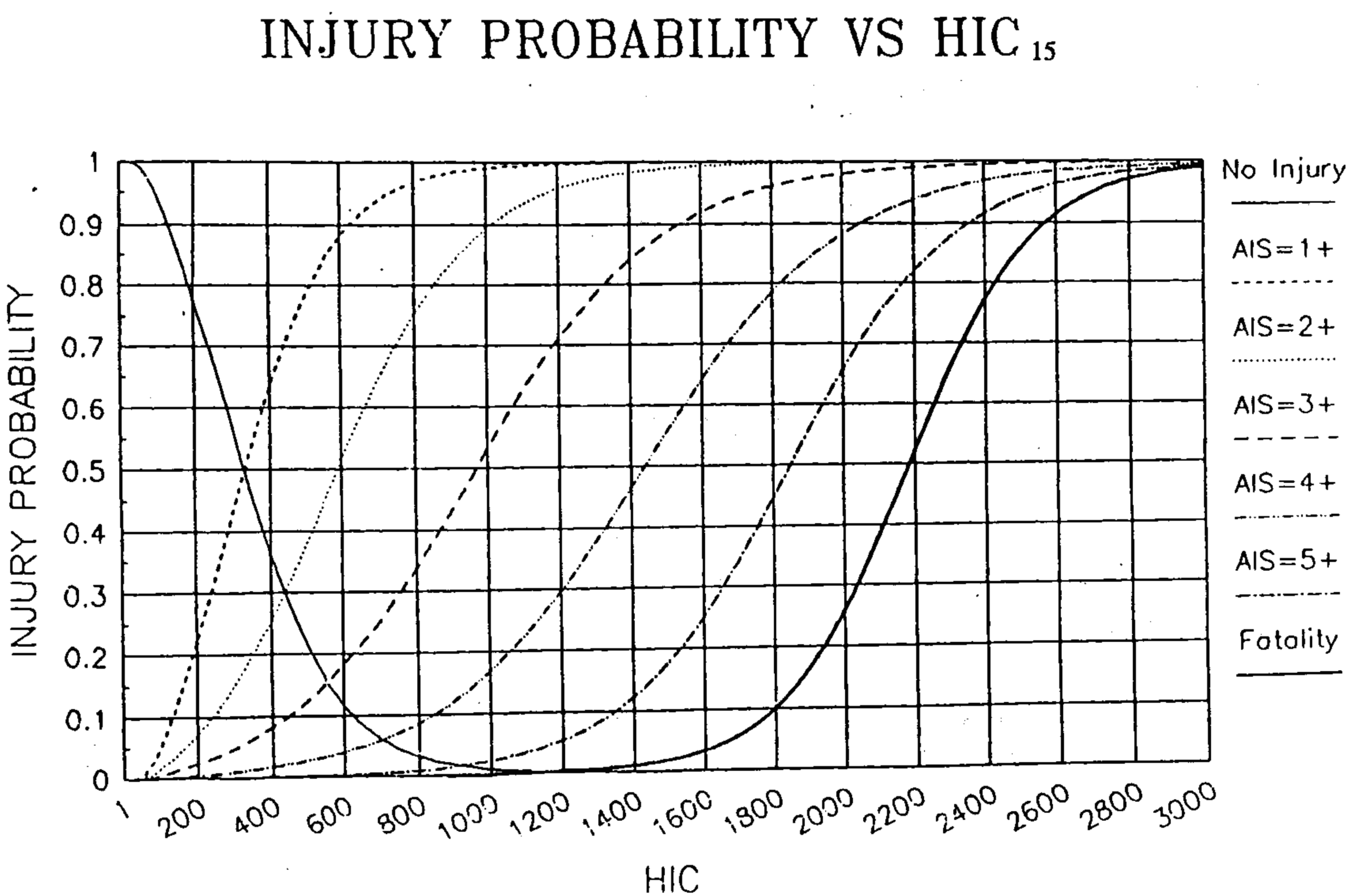
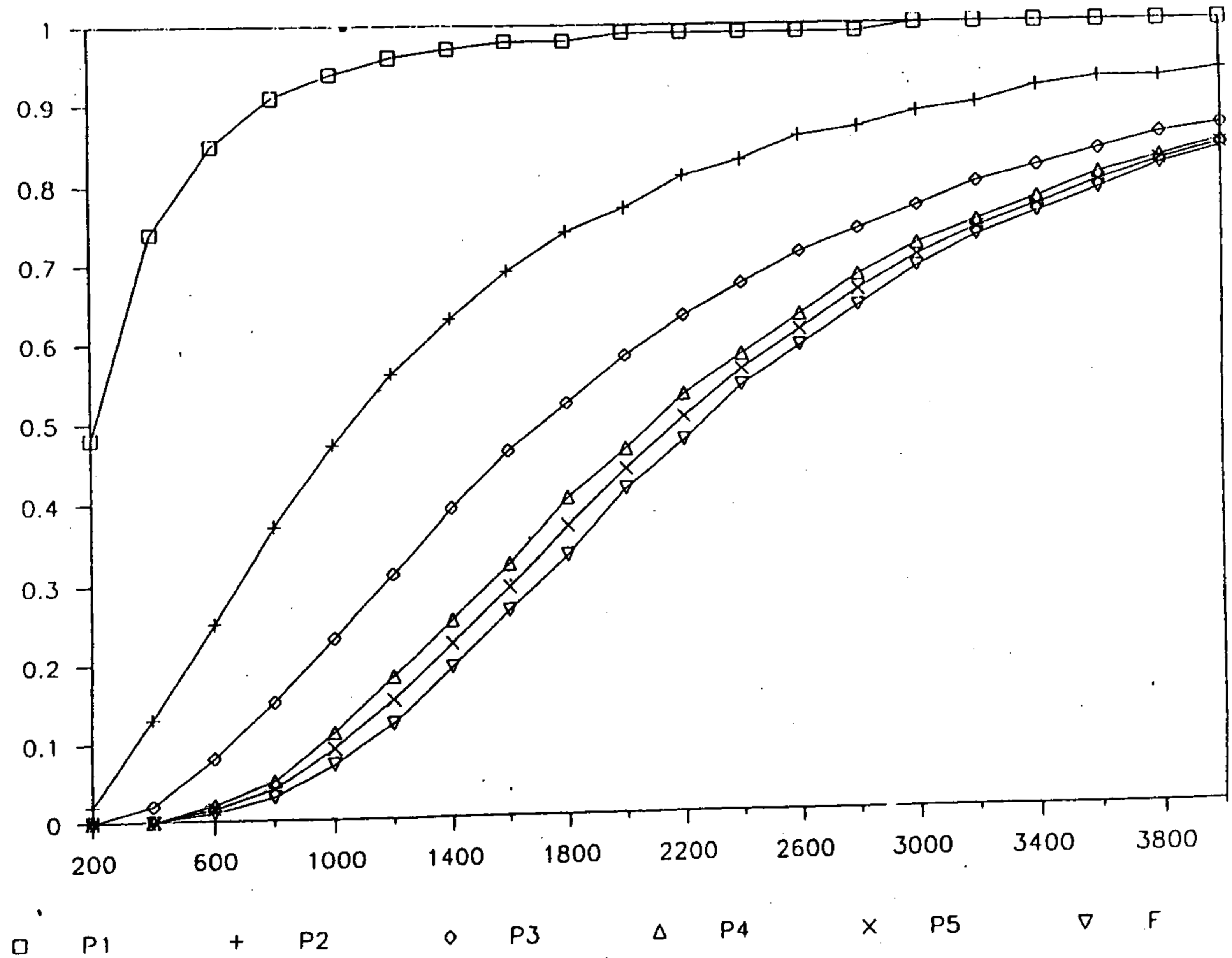


Figure III-2

Lognormal Head Injury Probability Curves
Injuries Greater Than or Equal to MAIS Level HIC_{15}



Neck Injury Criterion (Nij)

NHTSA is requiring the same neck injury criterion (Nij) as proposed in the SNPRM except with revised critical intercept values and new peak limits. The same neck injury risk curves used in the SNPRM apply to the final rule. As shown in Table III-1, the ICPL of 1.0 is required for all dummy sizes. This method combines neck axial tension/compression and neck moments (flexion/ extension) into one ICPL. This criterion employs the summation of normalized neck axial force and normalized neck moment at the occipital condyle. The formulation is $Nij = F_{NZ} + M_{NY}$, where: $F_{NZ} = F_Z / F_{Z\,CRIT.}$ and $M_{NY} = M_Y / M_{Y\,CRIT.}$ The measured neck values are; F_Z = neck axial load (tension or compression) and M_Y = neck bending moment (flexion or extension) at the occipital condyle. F_Z and M_Y are measured at the same point in time. The $F_{Z\,CRIT.}$ and $M_{Y\,CRIT.}$ values by dummy size are shown in Table III-1. Nij can not exceed 1.0 at any point in time. The critical intercept values shown in Table III-1 create a "kite" shaped boundary for both in-position and OOP test conditions. The peak limits for neck tension and compression, also shown in Table III-1, are used to truncate the upper and lower apexes of the "kite" shape thus creating an "hexagon" shaped boundary. Inside the hexagonal shaped boundary Nij is less than 1.0 and on the boundary line Nij = 1.0.

As shown in Table III-1, NHTSA is requiring critical intercept values for axial neck tension/ compression ($F_{Z\,crit.}$) as well as neck flexion/ extension moment ($M_{Y\,crit.}$) to be used in computing Nij for each dummy size. This approach (the so-called "Kite" Method described in the SNPRM) is based on a dependent relationship between neck axial loads and neck moments in assessing neck injury risk. Prasad and Daniel (SAE #841656) suggested that a linear combination of axial load and bending moment is a better predictor of injury than the individual limits.[8] The neck shear load is only used for the calculation of the My moment at the occipital condyles. Figure III-3 shows an example of the Nij related critical neck values and the formation of a "kite" shape, which has been modified with the peak limits for neck tension and compression, thus creating a hexagonal boundary for Nij less than or equal to 1.0, for the in-position 50th percentile male dummy. Figure III-4 illustrates the hexagonal boundary for Nij less than or equal to 1.0 for the in-position and out-of-position 5[th] percentile female dummy.

The formulas for Percent Injury Probability at AIS-2+ through AIS-5+ injury, as a function of Nij values are as follows:

AIS-2+ Percent Injury Probability = $[1/(1 + \exp^{(2.0536 - 1.1955*Nij)})] \times 100\%$.

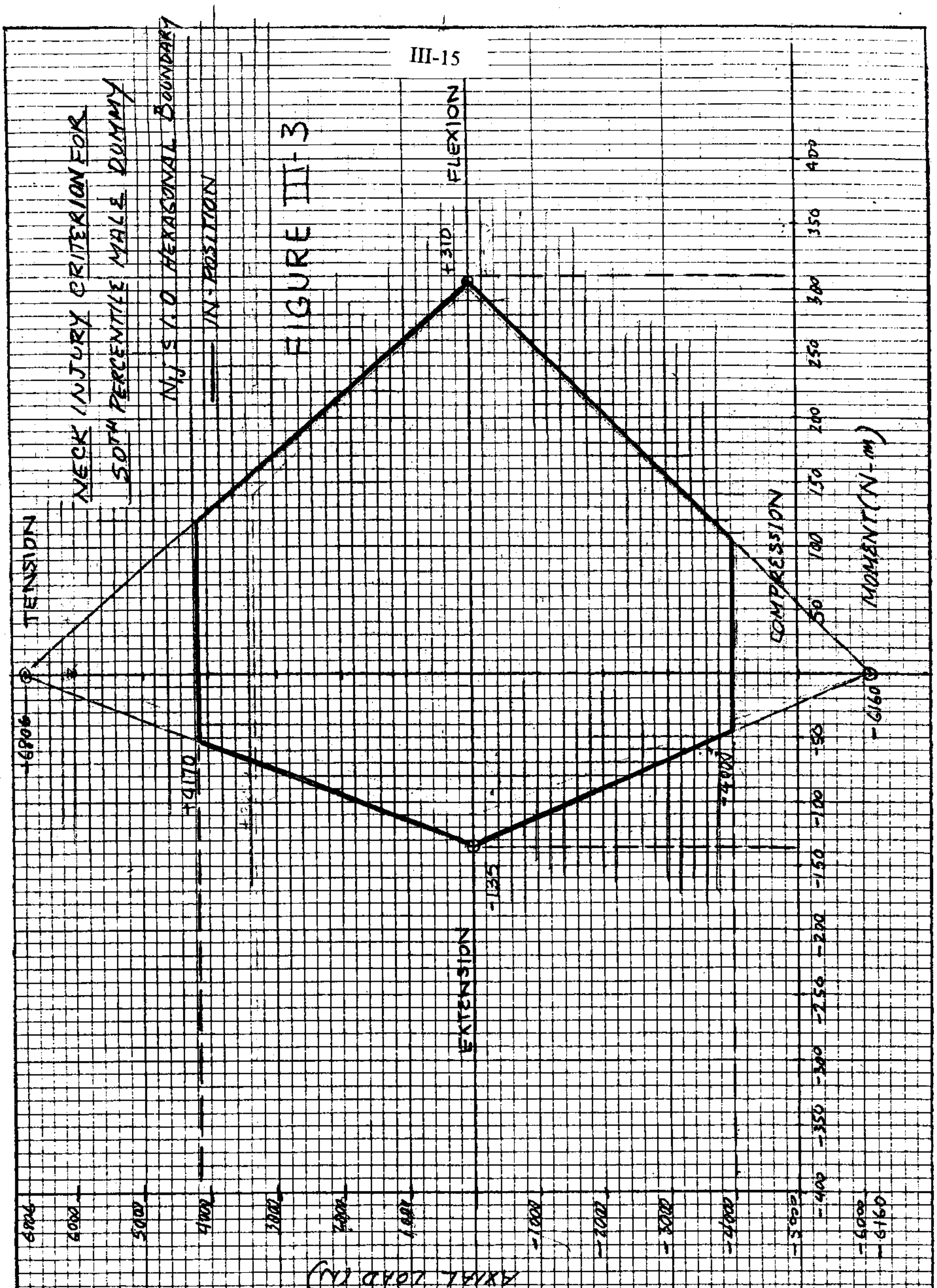
AIS-3+ Percent Injury Probability = $[1/(1 + \exp^{(3.227 - 1.969*Nij)})] \times 100\%$.

AIS-4+ Percent Injury Probability = $[1/(1 + \exp^{(2.693 - 1.196*Nij)})] \times 100\%$.

AIS-5+ Percent Injury Probability = $[1/(1 + \exp^{(3.817 - 1.196*Nij)})] \times 100\%$.

Fatality Percent Injury Probability = $[1/(1 + \exp^{(3.817 - 1.196*Nij)})] \times 100\%$. (Same as AIS-5+)

[8] A Biomechanical Analysis of Head, Neck and Torso Injuries to Child Surrogates Due to Sudden Torso Acceleration, Prasad, P. and Daniel, R.P., 1984 SAE International Congress and Exposition, Paper # 841656.


NECK INJURY CRITERION FOR
50TH PERCENTILE MALE DUMMY
NIJ = 1.0 HEXAGONAL BOUNDARY
IN-POSITION
FIGURE III-3
TENSION
COMPRESSION
FLEXION
EXTENSION
+6806
+4170
-4000
-6160
+310
-135
AXIAL LOAD (N)
MOMENT (N-m)
6806
6000
5000
4000
3000
2000
1000
-1000
-2000
-3000
-4000
-5000
-6000
-6160
400
350
300
250
200
150
100
50
-50
-100
-150
-200
-250
-300
-350
-400

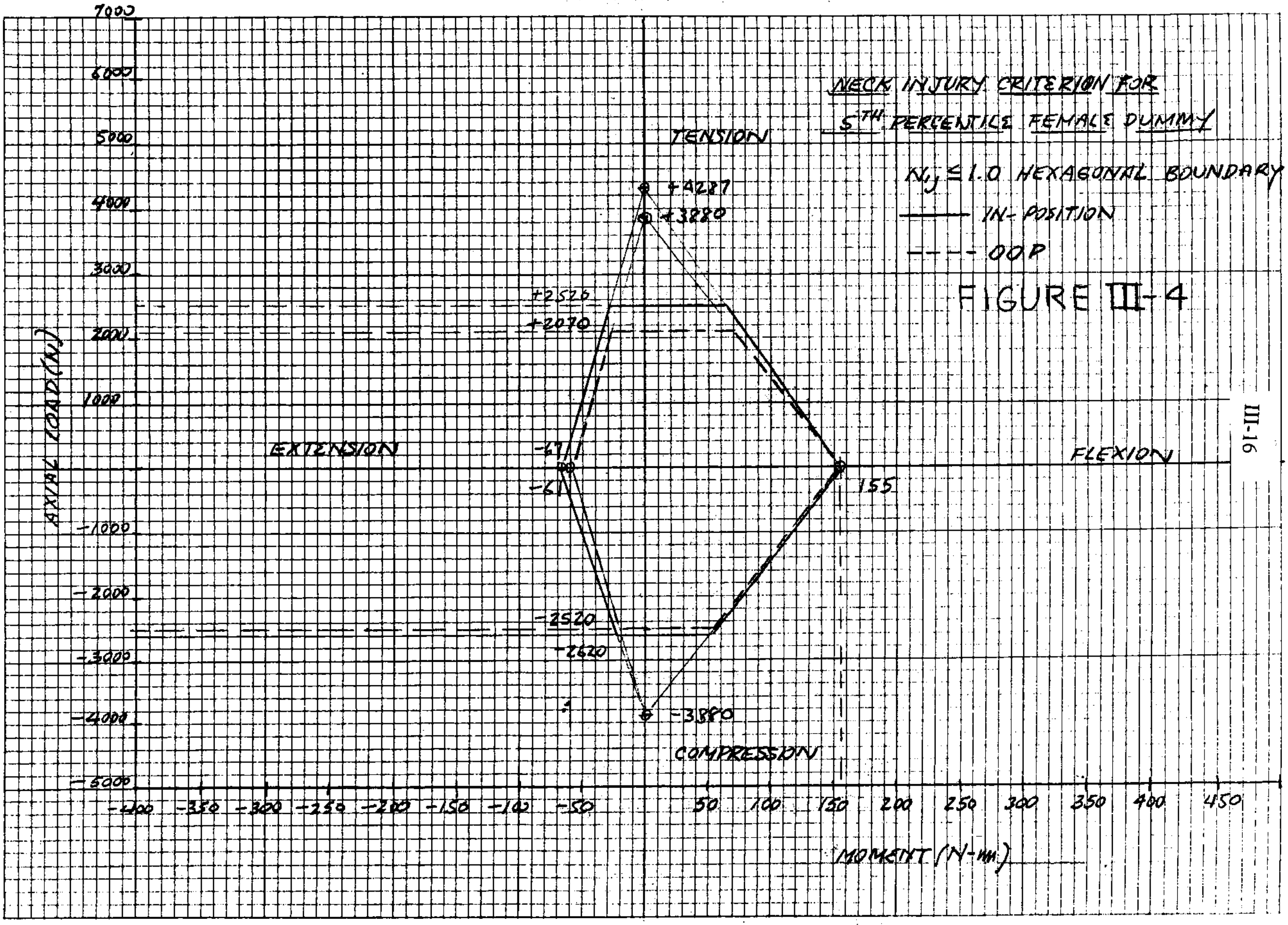

NECK INJURY CRITERION FOR
5TH PERCENTILE FEMALE DUMMY
$N_{ij} \leq 1.0$ HEXAGONAL BOUNDARY
IN-POSITION
OOP
TENSION
COMPRESSION
EXTENSION
FLEXION
+4287
+3880
+2526
+2070
-47
-61
155
-2520
-2620
-3880
AXIAL LOAD (N)
MOMENT (N-m)
7000
6000
5000
4000
3000
2000
1000
-1000
-2000
-3000
-4000
-5000
-400
-350
-300
-250
-200
-150
-100
-50
50
100
150
200
250
300
350
400
450

FIGURE III-4

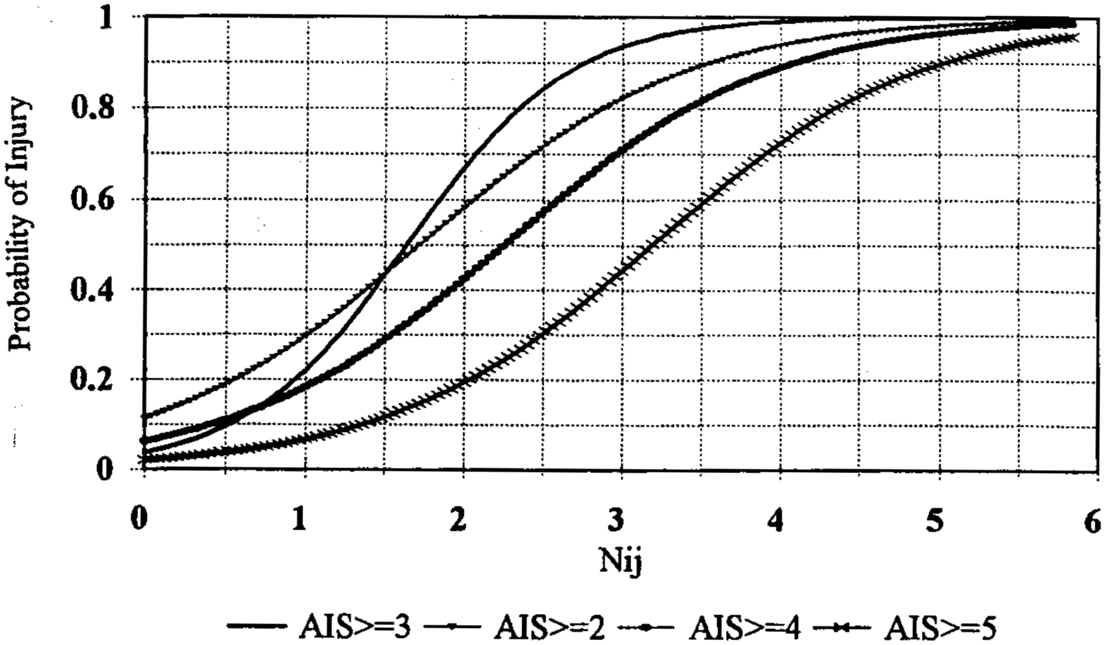
The probability of injury as a function of Nij for a family of risk curves is shown in Figure III-5. The Nij formula is the same regardless of dummy size because the critical values, $F_{Z\ CRIT.}$ and $M_{Y\ CRIT.}$ are scaled.

Nij Calculation

Regardless of dummy size, NHTSA is requiring that the biomechanical neck injury criteria, Nij (max.), not exceed a value of 1.0 at any point in time. The following procedure is used to compute Nij. The axial force (Fz) tension/compression and the neck flexion/extension moment about the occipital condyle (My) are used to calculate four combined injury predictors, collectively referred to as Nij. Nij (in Index Notation format) represents four combinations of loads that predict injury outcome. These four combined values represent the probability of sustaining each of the four primary types of cervical injuries, namely tension-extension (N_{TE}), tension-flexion (N_{TF}), compression-extension (N_{CE}) and compression-flexion (N_{CF}) injuries. Each measurement recorded by the upper neck load cell is first normalized against the critical intercept values for each specific dummy, where the normalized loads and moments can be expressed as: $F_{NZ} = F_Z / F_{ZCRIT.}$, and $M_{NY} = M_Y / M_{Y\ CRIT.}$ and where $F_{Z\ CRIT.}$ and $M_{Y\ CRIT.}$ are the critical intercept values previously discussed in Table III-1 for each specific dummy.

The critical intercept values for calculating the Nij are uniquely specified for each dummy and are defined in Table III-1 for the 50th percentile male, 5th percentile female, 6-year-old child, 3-year-old child and 12-month-old infant (CRABI) dummies. The peak limits on neck tension and

Figure III-5 **Probability of Injury vs. Nij**



compression create further Nij boundaries. The computed Nij value must fall within or on the hexagonal boundary. Source code for a C++ program to calculate the Nij criteria is included in Appendix of the supplemental biomechanics report. This source code, as well as executable version of the program, is also available from the NHTSA web site at http://www-nrd.nhtsa.dot.gov/nrd10/nrd12. The supplemental biomechanics report describes how the Nij calculation is made.

Chest Injury Risk Functions and ICPLs

The chest acceleration and chest deflection ICPLs proposed in the SNPRM for each dummy size have been adopted for the final rule. The mandated 63 mm (2.5") deflection for the 50th percentile male dummy represents a 33 percent chance of an AIS-3+ injury. The chest deflection threshold values for the other dummy sizes have been scaled from this adjusted value to maintain equivalent injury risk at maximum chest displacement. Figure III-6 illustrates the required thoracic injury criteria (D_C & A_C) for the 50th percentile male dummy.

Injury probability as a function of chest acceleration based on a 3 ms clip of the spinal acceleration on the 50th percentile male dummy is given below.[9] This acceleration is designated A_C for purposes of the subject Final Economic Assessment (FEA). The chest acceleration threshold values for the other dummy sizes were scaled from the 50th percentile male. The family of chest acceleration risk curves for the 50th percentile male dummy is illustrated in Figure III-7.

[9] The spinal acceleration is measured by accelerometer on the 50th percentile dummy at a point identified as T1. This has been re-designated as chest acceleration A_C for this report.

AIS-2+ Percent Injury Probability = $[1/(1 + \exp^{(1.2324 - 0.0576 * Ac)})] \times 100\%$.

AIS-3+ Percent Injury Probability = $[1/(1 + \exp^{(3.1493 - 0.0630 * Ac)})] \times 100\%$.

AIS-4+ Percent Injury Probability = $[1/(1 + \exp^{(4.3425 - 0.0630 * Ac)})] \times 100\%$.

AIS-5+ Percent Injury Probability = $[1/(1 + \exp^{(8.7652 - 0.0659 * Ac)})] \times 100\%$.

Injury probability as a function of maximum chest deflection (D_C) at the center of the chest for the 50th percentile male dummy is described below. The family of risk curves for chest deflection is illustrated in Figure III-8.

AIS-2+ Percent Injury Probability = $[1/(1 + \exp^{(1.8706 - 0.04439 * Dc)})] \times 100\%$.

AIS-3+ Percent Injury Probability = $[1/(1 + \exp^{(3.7124 - 0.0475 * Dc)})] \times 100\%$.

AIS-4+ Percent Injury Probability = $[1/(1 + \exp^{(5.0952 - 0.0475 * Dc)})] \times 100\%$.

AIS-5+ Percent Injury Probability = $[1/(1 + \exp^{(8.8274 - 0.0459 * Dc)})] \times 100\%$.

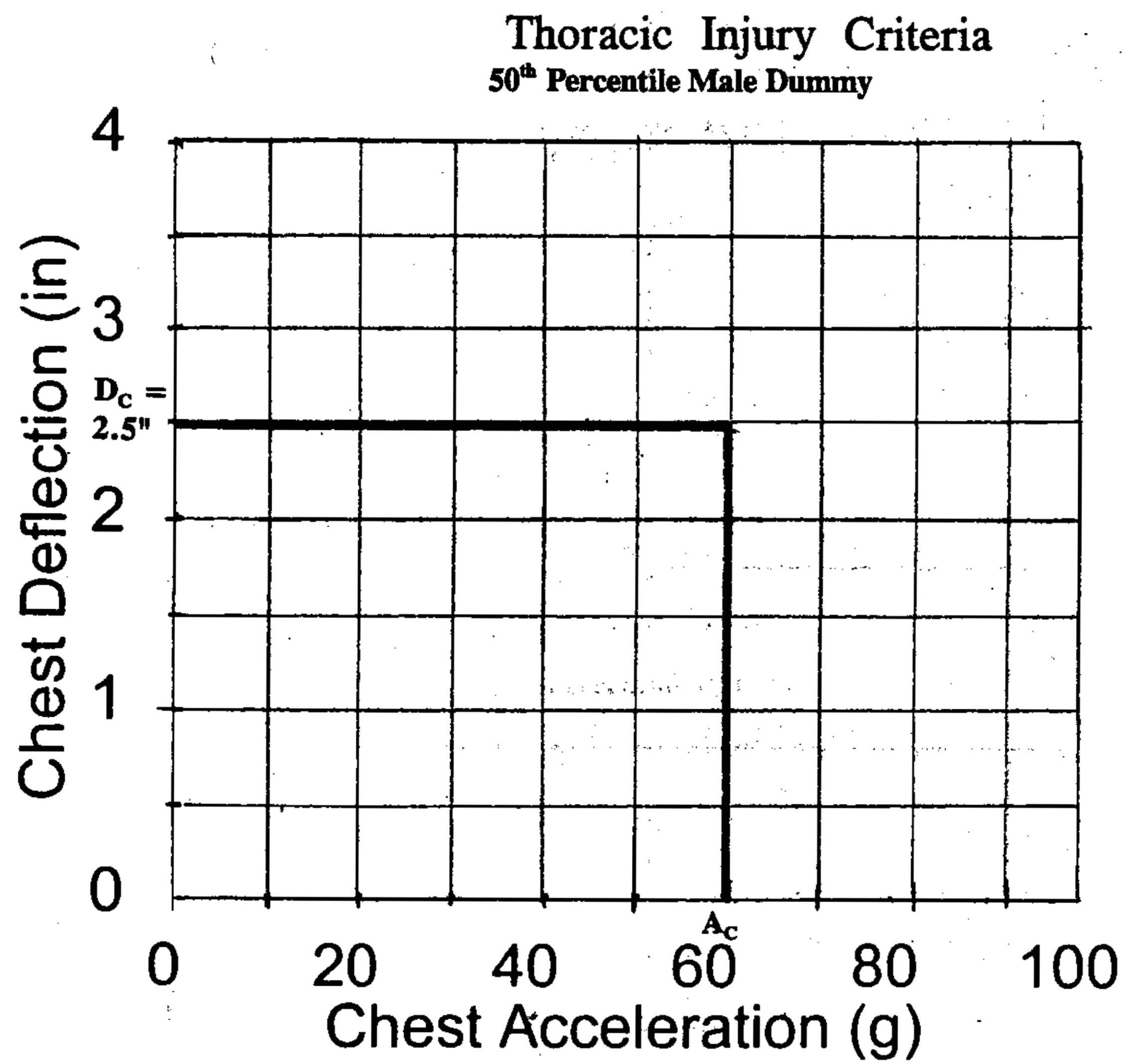


Figure III-6 **Thoracic Injury Criteria for the 50th Percentile Male Dummy showing Critical Chest Deflection (D_C) and Critical Chest Acceleration (A_C).**

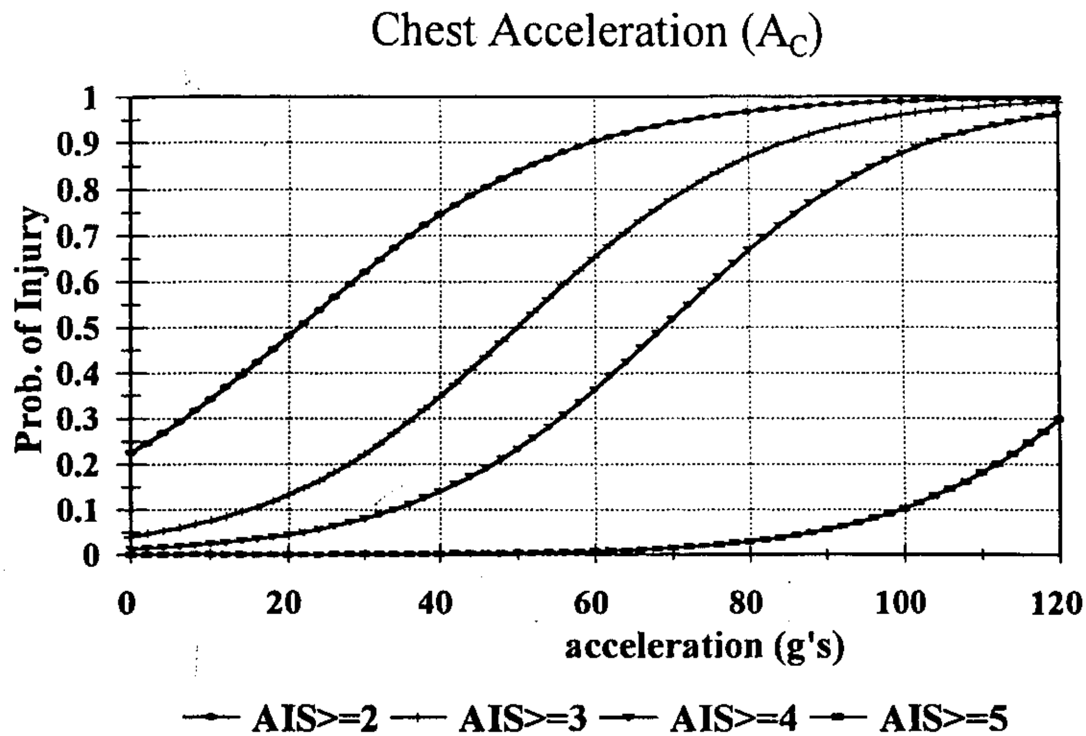


Figure III-7 Family of Chest Acceleration (A_C) Risk Curves for the 50th Percentile Male Dummy

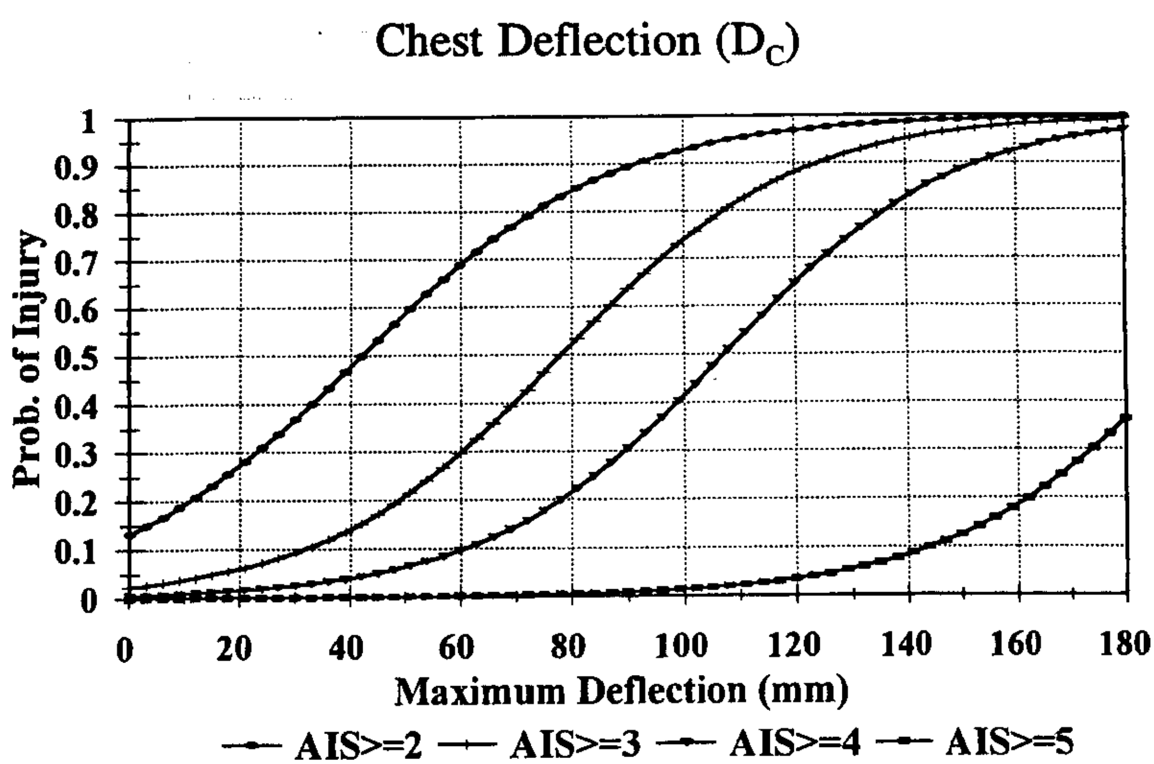


Figure III-8 Family of Chest Deflection (D_C) Risk Curves for the 50th Percentile Male Dummy

Combined Thoracic Index (CTI) Adopted for Chapter V. Benefits, for Analysis Purposes

Based on the analysis of the docket comments (98-4405), NHTSA proposed independent chest g's and chest deflection measures for the SNPRM, specifically, 60 g's and 63 mm (2.5 in.) for the 50th percentile male dummy. These independent ICPLs have been adopted for the final rule for the 50th percentile male dummy. The other dummy sizes are scaled from this, based on geometry and material properties. NHTSA proposed a new chest injury criterion called the Combined Thoracic Index (CTI) in the NPRM. Although not adopted for the subject final rule, the agency has adopted the CTI injury risk function for purposes of assessing chest injury risk reduction and subsequent benefits. For the purposes of benefits analysis, rather than assess risk for each independent chest injury criterion, it is more convenient and more correct, to adopt the CTI risk function where the two independent chest injury criterion are combined.

CTI is the summation of the normalized 3 ms clip chest g's and the normalized chest deflection. The normalized 3 ms chest g's is found by dividing the specific dummy chest g's response (A_{max}), for a given test, by the chest acceleration critical intercept value (A_{int})for the specific size dummy. The normalized chest deflection is found by dividing the specific dummy chest deflection response (D_{max}), for a given test, by the chest deflection critical intercept value (D_{int})for the specific size dummy. The formulation is: $CTI = [(A_{max} / A_{int.}) + (D_{max} / D_{int.})]$, where $A_{max.}$ is the maximum chest acceleration (g's) measured, $A_{int.}$ is the X-axis intercept value (specific to each dummy) for chest acceleration (g's), $D_{max.}$ is the maximum chest deflection (mm) measured and $D_{int.}$ is the Y-axis intercept value (specific to each dummy) for chest deflection (mm). Compared to the NPRM, the constants (D_{int} and A_{int}) in the CTI formula have been adjusted slightly in response to docket comments (98-4405) as shown in Table III-4.

Compared to other chest injury predictors studied by NHTSA, and based on the agency's cadaveric data, CTI is a better predictor of chest injury than chest acceleration or chest deflection alone. However, there are still questions regarding the interpretation of the data used in the development of CTI. More data and analysis is needed to evaluate the efficacy of a CTI based injury criteria.

Analysis of the cadaveric data indicates that if sternal deflection is plotted along the vertical axis and chest acceleration is plotted along the horizontal axis, a line drawn between the coordinates (0,4) and (90,0) would represent a 50 percent probability of an AIS-3+ injury for the population of cadavers studied (mean age 60 years). Because of the increased fragility of the cadavers and the age difference between the cadaver population studied and the human population, the actual risk of injury for an IARV of 1.0, for example, for CTI is estimated to be a 25 percent probability of an AIS 3+ for the driving population. Table III-4 shows the chest deflection Y-axis intercept (D_{int}) and the chest acceleration X-axis intercept (A_{int}) to set-up the 50 percent AIS-3+ threshold for each dummy size. Deflection and acceleration limits for each dummy size were obtained using geometric scaling from Mertz along with bone modulus scaling from Melvin.

Table III-4
Critical Intercept Values (D_{int} and A_{int}) for the CTI = 1.0 by Dummy Size
Used for Analysis Purposes Only.

	50th Percentile	**5th Percentile**	**6-Year-Old Child**	**3-Year-Old Child**	**12-Month-Old Infant (CRABI)**
D_{int} (Chest Deflection, Y-Axis Intercept)	103 mm (4.0")	84 mm (3.3")	64 mm (2.6")	57 mm (2.2")	50 mm (2.0")
A_{int} (Chest Acceleration, X-Axis Intercept)	90	90	90	74	57

Figure III-9 shows an example of D_{int} and A_{int} used to establish the CTI=1.0 threshold for the 50th percentile male dummy. Figure III-10 illustrates the family of CTI risk functions for AIS-2+, 3+, 4+, 5+ and fatal injury for the 50th percentile male dummy. The formula for percent injury probability at AIS-2+ through AIS-5+ injury, as a function of CTI values are as follows:

AIS-2+ Percent Injury Probability = $[1/(1 + \exp^{(4.847 - 6.036 \cdot CTI)})] \times 100\%$.

AIS-3+ Percent Injury Probability = $[1/(1 + \exp^{(8.224 - 7.125 \cdot CTI)})] \times 100\%$.

AIS-4+ Percent Injury Probability = $[1/(1 + \exp^{(9.872 - 7.125 \cdot CTI)})] \times 100\%$.

AIS-5+ Percent Injury Probability = $[1/(1 + \exp^{(14.242 - 6.589 \cdot CTI)})] \times 100\%$.

Fatality Percent Injury Probability = $[1/(1 + \exp^{(14.242 - 6.589 \cdot CTI)})] \times 100\%$. (Same as AIS-5+)

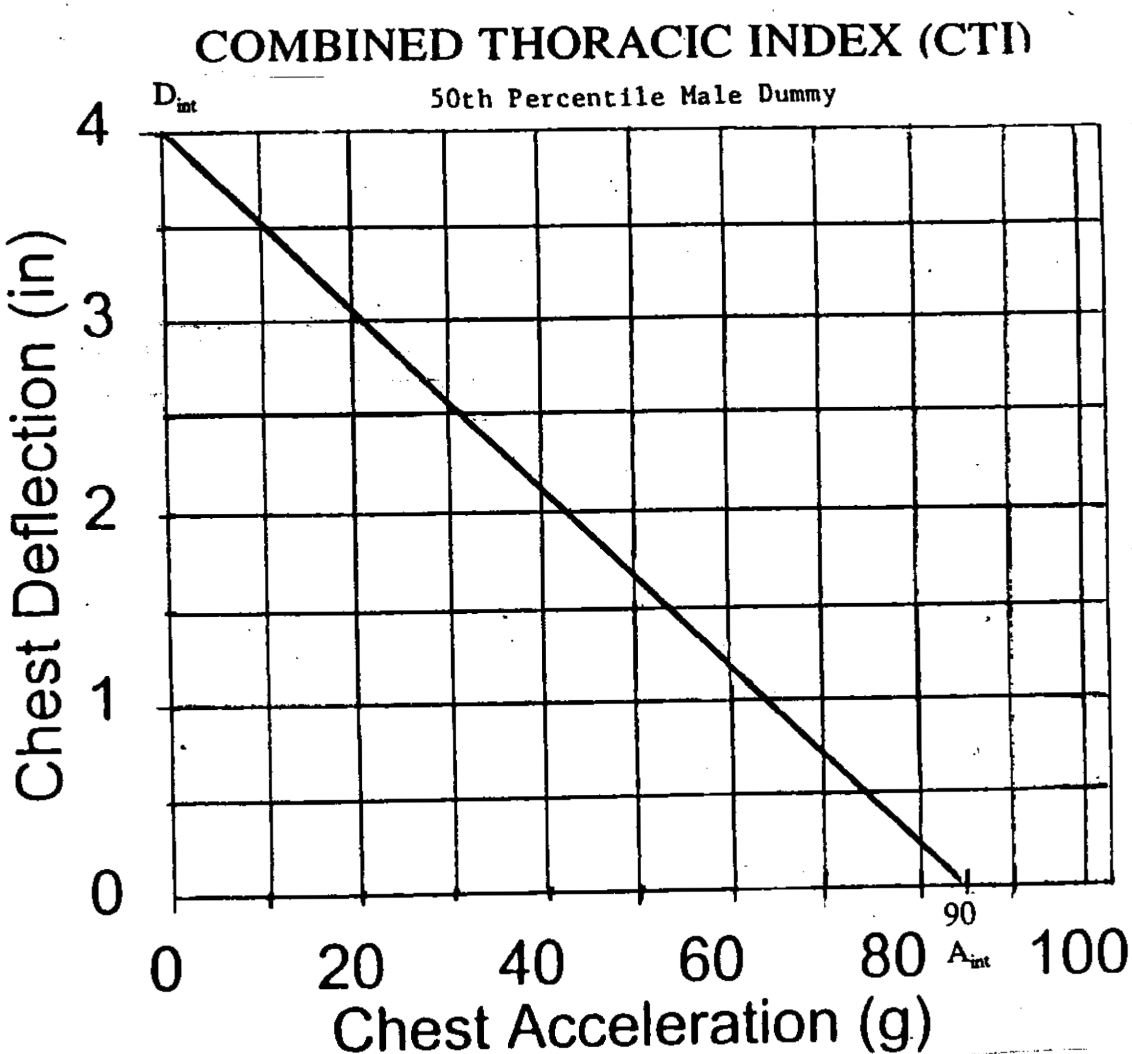


Figure III-9 Schematic of the Combined Thoracic Index (CTI) for the 50th Percentile Male Dummy showing the critical intercept values for Deflection (D_{int}) and Acceleration (A_{int}).

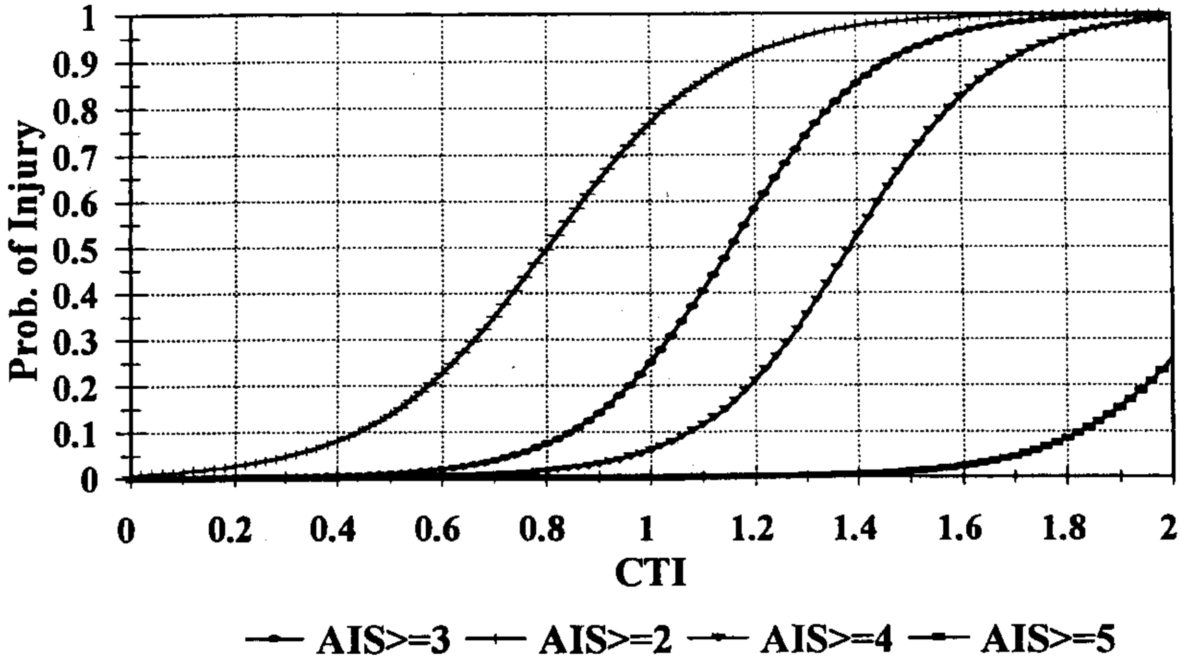


Figure III-10 Family of CTI Risk Curves

Femur Risk Function and ICPLs

As shown in Table III-1, femur axial load limits for the 50th percentile male and 5th percentile female dummies are being mandated in the final rule at 10 kN (2,250 lbs.) and 6.8 kN (1,530 lbs.), respectively. In frontal crashes, particularly with air bags, the dummy knees often make contact and load the instrument panel or knee bolster. NHTSA has estimated that for the 50th percentile dummy, 10 kN (2,250 lbs.) femur axial compression represents a 35 percent risk of an AIS 2+ injury. The AIS-2+ risk function for the 50th percentile male dummy is [$1/1+e^{(5.795-0.5196Fx)}$] times 100%], where Fx is the femur axial load measured in kN. Figure III-11 illustrates this risk function. The 5th percentile femur ICPL of 6.8 kN (1,530 lbs.) was scaled from the 50th percentile dummy values using 5th percentile female femur bone cross-sectional area. NHTSA is not adopting femur ICPLs for the 12-month-old infant (CRABI), the 3-year-old or the 6-year-old child dummies. Lower extremity injuries (femur fractures) are rarely experienced for OOP children.

C. Injury Criteria and IARVs for Analysis Purposes

95th Percentile Male Dummy IARVs

Table A-9, Driver and Passenger Sled Test Data with 95th Percentile Dummies (Chest g's) (Appendix) describes a series of 95th percentile male dummy tests conducted by the agency. These tests at 48, 64, and 72 kmph (30, 40 and 45 mph) compare pre-depowered (1997) and depowered (1999) chest g's results for a Chevy Venture and a Buick Century. In order to interpret the significance of agency sled results it was necessary to derive appropriate IARVs for the 95th percentile dummy based on the same injury criteria required for the other dummies. Similar IARV values for the 95th percentile male dummy are shown in Table III-5.

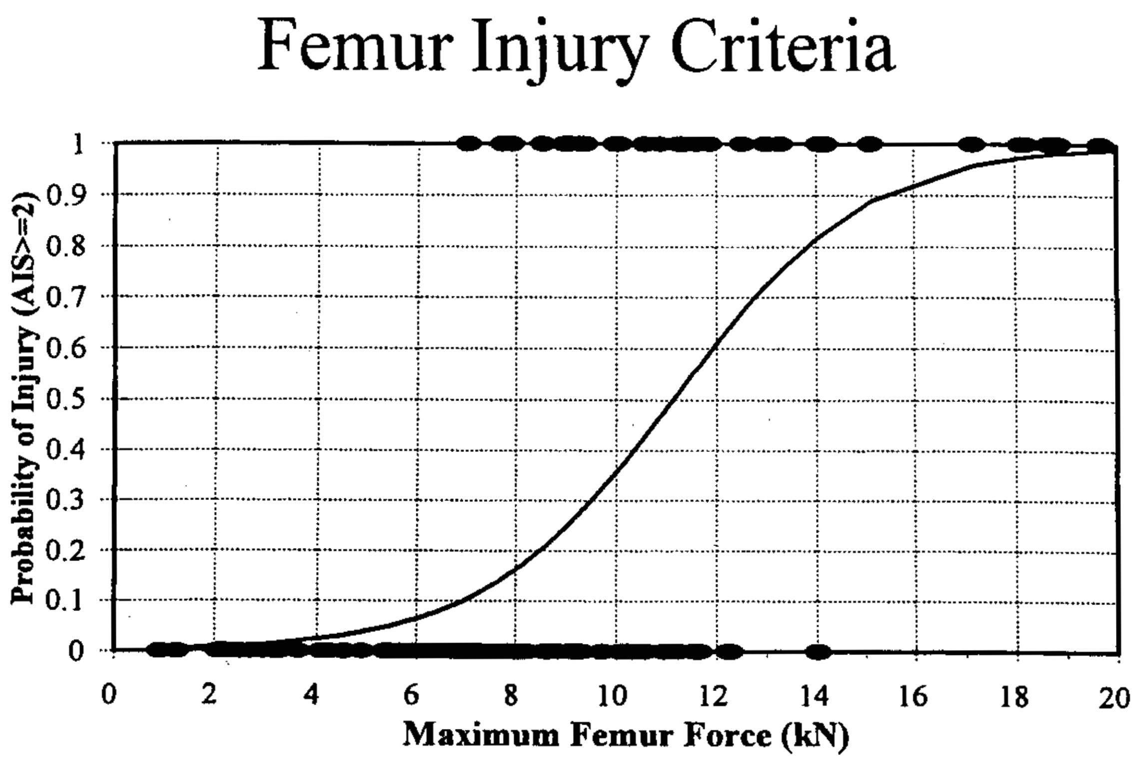


Figure III-11 Femur Axial Load Risk Curves (> = AIS-2+) for the 50th Percentile Male Dummy

Table III-5
Injury Criteria and Injury Assessment Reference Values (IARVs) derived for the 95th Percentile Male Dummy, Used for Analysis Purposes Only

Injury Criteria	Hybrid III 95th Percentile Male Dummy IARVs
Head Criteria HIC_{15ms}	700
Neck Criteria Nij	1.0
In-Position	
Nij Critical Intercept Values	
Fz crit. Tension (N)	8216
Fz crit. Compression (N)	-7440
My crit. Flexion (N-m)	415
My crit. Extension (N-m)	-179
Peak Limits	
Neck Tension (N)	5030
Neck Compression (N)	-4830
Out-of-Position	
Nij Critical Intercept Values	
Fz crit. Tension (N)	7440
Fz crit. Compression (N)	-7440
My crit. Flexion (N-m)	415
My crit. Extension (N-m)	-162
Peak Limits	
Neck Tension (N)	3970
Neck Compression (N)	-4830
Thoracic Criteria	
1. **T1**: Critical Spine Acceleration (g)	55
2. **D**: Critical Chest Deflection (mm)	70
3. Combined Thoracic Index (CTI)	
CTI Intercept values	
Aint. Accel. (G)	83
Dint. Deflection (mm)	114
Lower Extremity Criteria	
Femur Loads (kN)	12.7

IV. TEST DATA AND ANALYSIS OF TEST DATA

This chapter presents test data available to the agency on the various static and dynamic test procedures mandated by the advanced air bags final rule. The test data, and analysis of the test data, are presented in the following format.

A. Static Tests (Out-of-Position)

1. Driver-Side OOP 5th Percentile Female Dummy (MY99, MY98 and Pre-MY98 data)
   a. Position 1 (chin on module)
   b. Position 2 (chest on module)

2. Passenger-side OOP
   a. RFCSS 12-Month-Old Infant (CRABI) Dummy
   b. 6- Year-Old Child Dummy (MY99, MY98 and Pre-MY98)
      (1) Position 1 (chest on module)
      (2) Position 2 (head on module)

B. Vehicle Tests (In-Position)

1. Belted Tests
   a. 56 kmph (35 mph), 0 Degree, Belted Barrier Test
      (1) 50th Male

   b. 48 kmph (30 mph), 0 Degree, Belted Barrier Test
      (1) 50th Male.
      (2) 5th Female

   c. 40 kmph (25 mph), Offset Deformable Barrier (ODB), 40% Overlap, Belted Test
      (1) 5th Female

2. Unbelted Tests
   a. 40 kmph (25 mph), 0 Degrees, Unbelted Barrier Test
      (1) 50th Male.
      (2) 5th Female

   b. 48 kmph (30 mph), 0 Degree, Unbelted Barrier Test
      (1) 50th Male.
      (2) 5th Female

   c. 48 kmph (30 mph) +/- 30 Degree (L or R) Oblique Unbelted Barrier Test
      (1) 50th Male

C. Summary of Pass Rates by Required Test Procedure

D. Test Procedure Stringency

1. Out-of-Position Static Test Procedures
   a. 12-Month-Old Infant (CRABI) Dummy
   b. 5th Percentile Female Dummy
   c. 6-Year-Old Child Dummy
   d. 3-Year-Old Child Dummy

2. In-Position Dynamic Test Procedures
   a. Left vs Right Unbelted Oblique for 50th Percentile Male Dummy
   b. 50th Percentile Male vs 5th Percentile Female Dummy Dynamic and Compliance Equivalency
      (1) BMW Sled Tests, Unbelted
      (2) 48 kmph (30 mph), 0 Degrees, FRB, Unbelted
      (3) 48 kmph (30 mph), 30 Degrees Oblique (L), Unbelted

3. Nij (Final Rule) vs Nij (SNPRM)

A. Static Tests, Out-of- Position (OOP)

A.1.a. & b. **Driver 5th Percentile Female Dummy**

The final rule requires static out-of-position tests for the driver-side 5th percentile female dummy. Static deployment Position 1 and 2 tests were conducted using the 5th percentile female dummy representing the driver-side. These positions are the same as those proposed in the SNPRM where in Position 1 the dummy's chin is placed on the inflator module and Position 2 the dummy's chest is placed on the inflator module. Table IV-1 shows that HIC_{15}, chest g's and chest deflection did not have any failures for all the tests, whereas Nij had failures for both Position 1 and Position 2 testing based on MY98 and pre-MY98 vehicles. Compared to pre-MY98 vehicles, the magnitude of Nij has decreased in MY98 and MY99 and the Nij Pass Rates have subsequently improved. In MY99, the Nij Pass Rate improved to the 67 percent level for Position 1 and to the 100 percent level for Position 2.

Tables IV-2 and IV-3 show the individual Nij values by make/model/year used for the averages shown in Table IV-1.

Table IV-4 shows the individual chest deflection, chest g's and Nij values by make/model for 1996 versus 1998. Table IV-5 shows the same responses for individual MY99 make/models.

Passenger-Side OOP

Convertible Child Safety Seat and 12-Month-Old Infant (CRABI) Dummy

The new 12-month-old infant (CRABI) test dummy was tested on a 213 sled with and without air bags. The results are organized by common test condition in Table IV-6a. All tests utilized the standard FMVSS 213 sled pulse and 213 seat. The sled tests with air bag deployments used 1997 Ford Taurus or 1998 Ford Explorer air bag modules. These are labeled non-213 configuration, but used the 213 pulse and seat. The HICs measured were an order of magnitude lower using the 12-month-old CRABI dummy compared to previous VRTC tests (shown in the August 1998 PEA) using a 9-month-old dummy (TNO P3/4 dummy). Overall Pass Rates are zero percent for each test condition which are summarized in Table IV-15. In the final rule, the manufacturers have a suppression option for meeting this static OOP test.

Table IV-1
Summary of OOP Results by Model Year
Driver-5th Percentile Female Dummy[1]
Numbers in ( ) indicate Pass Rate in Percent

	HIC_{15} Avg.	Nij Avg.	Chest g's Avg.	Chest Deflect Avg.	What failed?	n
MY 99 5th Driver						
Pos.1	67 (100)	0.91 (67)	18.2 (100)	24.7 (100)	2/6 Nij failures	6
Pos.2	41 (100)	0.48 (100)	29.42 (100)	35.7 (100)	No Failures	6
MY 98 5th Driver *						
Pos.1	53 (100)	1.41 (0)	16.6 (100)	20 (100)	All failed Nij	5
Pos.2	109 (100)	0.906 (60)	26.7 (100)	34.7 (100)	2/5 failed Nij includes neck C failure	5
PRE-MY 98 5th Driver **						
Pos.1	149 (100)	1.60 (25)	23.43 (100)	26.7 (100)	2/4 failed Nij & neck T 1/4 failed neck T	4
Pos.2	73 (100)	1.85 (25)	26.64 (100)	39.11 (100)	3/4 failed Nij	4
5th % 1CPL	700	≤1.0	60	52		

* MY 99 and MY 98 are not matched by make/model. ** MY 98 and PRE-98 are matched by make/model. MY 99 and PRE-98 matched make/models were not tested.
Peak Limits for neck compress. (C) & tension (T) were not exceeded in these tests except as noted .

[1] The OOP tests were not conducted with original vehicle seats. The response of the dummy during contact with the seat back in these OOP tests may not be the same as when the test is conducted in the vehicle with original seats. The impact event was assessed up to 300 ms. The maximum injury value before seat back contact was recorded in this table.

Table IV-2
Static Out-of Position Driver Tests, Position 1, 5th Percentile Female Dummy
Max Nij

Vehicle	MY 1996 Nij	MY 1998 Nij
Ford Explorer	**2.76**	**1.20**
Ford Taurus	0.91*	**1.62**
Dodge Neon	**2.08**	**1.73**
Toyota Camry	0.66	**1.27**
Honda Accord	--	**1.24**

Bold Numbers indicate that the mandated ICPL values were exceeded.
-Peak Limits for neck compress. (C) & tension (T) were not exceeded in these tests except as noted. * Ford Taurus passed Nij, but failed neck T peak limit.

Table IV-3
Static Out-of Position Driver Tests, Position 1, 5th Percentile Female Dummy
Max Nij

Make/Model	MY 99 Nij	
Dodge Intrepid*	0.71	
Saturn SL1	0.26	
Ford Econoline (Van)	0.98	
Acura 3.5RL **	**1.34**	
Ford Expedition (SUV)	0.99	
Toyota Tacoma (PU)*	**1.17**	

* Indicate that sled bucks were used for these static tests.
** Acura 3.5 RL has a single stage inflator on the driver's side and dual stage inflator on the passenger's side.
-MY 99 and pre-MY 98 matched make/models were not available.
-MY 99 and MY 98 are not matched make/models.
- Peak Limits for neck compress. (C) & tension (T) were not exceeded in these tests except as noted .

Table IV-4
Static Out-of Position Driver Tests, Position 2
5th Percentile Female Dummy
Chest and Neck Measurements

	MY 1996	MY 1998
Chest Deflection (mm)		
Ford Explorer	39.77	22.6
Ford Taurus	43.68	38.69
Dodge Neon	43.32	34.43
Toyota Camry	29.36	32.90
Honda Accord		44.7
Chest g's		
Ford Explorer	36.4	13.95
Ford Taurus	20.58	27.55
Dodge Neon	31.64	34.05
Toyota Camry	17.96	31.74
Honda Accord		26.22
Nij		
Ford Explorer	**2.23**	**1.07**
Ford Taurus	**1.11**	0.99
Dodge Neon	**2.20**	**1.02**
Toyota Camry	0.73	0.80
Honda Accord		0.65

- **Bold Numbers** indicate that the mandated ICPL values were exceeded.
- Applicable ICPLs are: HIC_{15} = 700, Nij = 1.0, chest g's = 60 g's, chest deflection = 52 mm.
- Peak Limits for neck compress. (C) & tension (T) were not exceeded in these tests except as noted .

Table IV-5
Static OOP Driver Test Position 2
5th Percentile Female Dummy

	MY 99
Chest Deflection. (mm)	
Dodge Intrepid*	47.3
Saturn SL1	36.4
Ford Econoline	33.0
Acura 3.5RL	29.0
Ford Expedition	37.0
Toyota Tacoma*	31.3
Chest g's	
Dodge Intrepid*	40.0
Saturn SL1	22.9
Ford Econoline	24.9
Acura 3.5RL	26.4
Ford Expedition	32.2
Toyota Tacoma*	30.2
Nij	
Dodge Intrepid*	0.58
Saturn SL1	0.37
Ford Econoline	0.30
Acura 3.5RL	0.63
Ford Expedition	0.34
Toyota Tacoma*	0.66

* Indicates sled bucks were used for these static tests.
*MY 99 make/models matched to MY 98 or MY 96 make/models were not available for analysis.
- Peak Limits for neck compression (C) and tension (T) were not exceeded in these tests except as noted.

Tables IV-10, 11 and 12 in the Preliminary Economic Assessment (PEA) August, 1998 contained baseline 213 sled tests with a 9 month-old dummy as well as tests with air bags (mid-mount and top mount).[2] The maximum HIC_{36} using mid-mounted air bags ranged from 2,000-3,000 and the top mounted air bag HIC_{36} was as high as 3,015. The new VRTC test series involving the 12-month-old CRABI dummy shows that HICs have been reduced by about an order of magnitude despite being computed over 15 ms rather than 36 ms. The test conditions in this test series were identical to those referenced in the PEA.[3]

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[2] The 9-month dummy employed was designated the TNO P3/4 infant dummy.

[3] Preliminary Economic Assessment, FMVSS No. 208, Advanced Air Bags, August 1998, Office of Regulatory Analysis and Evaluation, Plans and Policy, NHTSA/DOT. Also, Preliminary Economic Assessment, October 1999, SNPRM, FMVSS No. 208, Advanced Air Bags, Office of Regulatory Analysis and Evaluation, Plans and Policy, NHTSA/DOT.

Tables IV-6a
FMVSS No. 213 Sled Tests
12-Month-Old Infant (CRABI) Responses

Test Condition 1./	**Test #**	**Child Seat Facing**	**HIC15 (ICPL ≤390)**	**Nij (ICPL≤1.0)**
Convertible Child Seat w/o Air Bag (FMVSS 213 pulse and configuration)	2R	F	239	**1.34***
	5	F	**411**	**1.30 ***
	9	F	214	**1.06***
	10	F	303	**1.12***
	11R	F	232	**1.14***
	1R	R	**565**	**1.51***
	6	R	241	**1.49***
	12	R	130	1.12
Convertible Child Seat with Air Bag (FMVSS 213 pulse but non-213 configuration) 2./ & 3./	3M	F	329	**1.32**
	4M	R	**1555**	**1.27***
	7T	F	**662**	**1.03**
	8T	R	**531**	**1.41**

Bold Numbers exceed the mandated ICPL values.
FMVSS No. 213, Child Restraint Systems.
R = Convertible Child Seat Rearward-Facing. F = Convertible Child Seat Forward-Facing.
1./ For test conditions, see VRTC report on CRABI dummy, Docket NHTSA-99-5156-6.
2./ 1997 Ford Taurus and 1998 Ford Explorer inflators.
3./ #3 and #4 are mid-mount air bags (M) were 1998 Ford Explorer modules. #7 and #8 are top mount air bags (T) were 1997 Ford Taurus modules.
* Asterisk indicates peak limit neck tension failure as well as Nij failure.

NHTSA also conducted a 12-month-old infant (CRABI) low risk deployment test using new inflator technology, namely, - the 1st stage of an experimental (confidential MMY) dual stage inflator. The vehicle's passenger seat was placed full-forward with the seat back set at 30 degrees. The top center of the Century rear facing child safety seat (RFCSS) was aligned with the geometric center of the air bag. The center line of the RFCSS was aligned with the longitudinal center line of the test vehicle. The vehicle safety belts were cinched to secure the RFCSS. The 12-month-old infant dummy was belted in the Century RFCSS. The first stage of an experimental dual power experimental air bag was statically deployed.[4] Table IV-6b shows that all the responses of the 12-month-old infant dummy were low and would pass the mandated ICPL requirements. The Nij calculated per the final rule was less than 1.0 and peak limits for neck compression/tension, out-of-position (OOP), were not exceeded.

Table IV-6b
Low Risk Deployment Test (n=1) with the 12-Month-Old Infant (CRABI) Dummy
1st Stage of Experimental Dual Power Inflator

Injury Criteria	CRABI Responses	ICPLs	Pass/Fail
HIC_{15}	321	390	P
Neck Tension (N) Peak Limits OOP	447	780	P
Neck Comp. (N) Peak Limits OOP	195	960	P
Nij	0.47 (N_{TE})*	1.0	P
Chest g's	23	50	P

VRTC Test No. 04200034.
* Peak Limits for neck compression (C) and tension (T) were not exceeded in this test.

6-Year-Old Child Dummy (Passenger-side)

The final rule requires static out-of-positions tests for the 6-year-old child dummy. The static deployment OOP Positions 1 and 2 (0 mm clearance) were tested using the 6-year-old child dummy. Positions 1 and 2 were the same as those required in the final rule such that in Position 1 the chest is placed on the module, whereas for Position 2, the head is placed on the module. As

[4] Evaluation of the CRABI 12-Month-Old Infant Dummy and Its Comparison with TNO P3/4, February, 1999, Hagedorn, A.V. and Pritz, H.B., Vehicle Research and Test Center, East Liberty, OH, Docket No. NHTSA-99-5136-6.

shown in Table IV-7, HIC_{15} passed in either Position 1 or Position 2 tests using MY99 vehicles or test bucks. [Note: Model year 1998 and pre-model year 1998 vehicles are matched. MY98 and MY99 vehicles are not matched by make/model.] Nij, chest g's, and chest deflection, however, did not always pass using Position 1 and Position 2 procedures based on MY98 and 99 vehicles or sled test bucks. Position 2 tests were not conducted in MY98 or pre-MY98. HIC_{15}, chest g's and chest deflection have improved with the new redesigned air bags. Similarly, Nij values have improved, but there is still a low Nij Pass Rate in MY98 and 99 vehicles.

Table IV-7
Summary of OOP Results by Model Year
Passenger 6-Year-Old Child Dummy
Number in (   ) indicates Pass Rate in Percent

	HIC_{15} Avg.	Nij Avg.	Chest g's Avg.	Chest Deflect Avg.	What failed?	n
MY 99 6 Year Old Passenger (0 mm)						
Position 1	169 (100)	1.76 (33)	32.63 (100)	31.48 (42.9)	4/7 - Nij (2 failed T) 1/6 neck T 4/7 - Deflect	7
Position 2	246 (100)	2.05 (28.6)	48.37 (57.1)	27.53 (71.4)	5/7 - Nij (5 failed T) 3/7 - Chest g 2/7 - Deflect	7
MY 98 6 Year Old Passenger (0 mm)						
Position 1	542 (83)	3.51 (0)	39.5 (83)	40.75 (16.7)	1/6 - HIC_{15} 6/6 - Nij (6 failed T) 1/6 - Chest g 5/6 - Deflect	6
Position 2	***					
Pre-MY98 6-Year-Old Passenger (0 mm)						
Position 1	938 (50)	4.50 (0)	52.85 (67)	48.4 (16.7)	3/6 - HIC_{15} 5/5 - Nij 2/6 - Chest g 5/6 - Deflect	6
Position 2	***	***	***	***		
6YO ICPLs	700	1.0	60	40		

* MY 99 vehicles are not matched to MY 98 by make/model. ** MY 98 and Pre-MY 98 are matched by make/model. *** These tests not conducted.

- Peak Limits for neck compression (C) and tension (T) were not exceeded in these tests except as noted.

Tables IV-8a and IV-8b contain the specific 6-year-old dummy responses by make/model for MY96, MY98 and MY99 for static OOP Position 1 with zero clearance. Tables IV-8b and IV-8c show a 100 percent Pass Rate for OOP Positions 1 and 2 for the Acura 3.5RL using the first stage of a two stage inflator.

Table IV-8a
Static Out-of-Position Tests with a 6-Year- Old Child Test Dummy
Position 1 @ 0 mm Clearance from the Air Bag Module

Vehicle	MY 96 HIC 15	MY 98 HIC15	MY 96 Chest g's	MY98 Chest g's	MY 96 Chest Deflect	MY98 Chest Deflect	MY 96 Nij	MY 98 Nij
Ford Taurus	**2471**	**1854**	53.8	**64**	28	**50.5**	**3.66**	**2.84**
Dodge Neon	377	172	35.7	22.3	**43.8**	**41.8**	**3.20**	**2.75**
Toyota Camry	**1020**	213	**64.6**	32.8	**45.4**	11.3	**9.06**	**3.79**
Dodge Caravan	**1207**	493	**82.9**	30.7	**50**	**50.6**	N.A.	**3.41**
Honda Accord	N.A.	132	N.A.	37	N.A.	**40.1**	N.A.	**2.11**
Ford Explorer	276	387	42.5	50.2	**63**	**50.2**	**2.90**	**6.16**
Ford Explorer	278	-	37.5	-	**60.2**	-	**3.70**	-
ICPL	700	700	60		40		≤1.0	≤1.0

Bold Numbers exceed the mandated ICPL values.
N.A. indicates data Not Available
- Peak Limits for neck compression (C) and tension (T) were not exceeded in these tests except as noted.

Table IV-8b
Static Out-of-Position Tests With a 6-Year-Old Child Dummy
Position 1 @ 0 mm Clearance from the Air Bag
Module for MY 99

MY 99	**HIC_{15}**	**Nij**	**Chest g's**	**Chest Deflection (mm)**
Dodge Intrepid	149	**2.89**	58.93	**42.1**
Saturn SL1	35	0.93	23.1	**44.2**
Ford Econoline	428	---	50.3	**45.1**
Acura 3.5RL*	101	**1.31**	19.5	10.7
Acura 3.5RL**	87	0.94	19.4	6.9
Ford Expedition	42	**1.04**	39.2	**49.8**
Toyota Tacoma	145	**3.44**	17.9	21.9
ICPLs	700	≤1.0	60	40

Bold Numbers exceed the mandated ICPL values.
* Stage 1 fired and then Stage 2 fired with a 40 ms delay.
** Stage 1 fired only
Peak Limits for neck compression (C) and tension(T) were not exceeded except as noted. Saturn SL1 had an Nij of 0.93, but failed neck T peak limit @ 1,799 N.

In their docket comments (Docket No. 99-6407-47), Toyota submitted a tank pressure vs. time performance curve for a Honda Acura dual stage inflator and stated that NHTSA's "Stage 1 fired only" tests shown in Tables IV-8b and IV-8c may be invalid. The performance curve submitted by Toyota shows a second stage firing at approximately 40-42 ms and a sudden increase in pressure. This was the type of inflator believed to be used by NHTSA/VRTC. Toyota indicated the second stage (Stage 2) could fire anywhere from 33 to 110 ms. Honda did not comment on these two tests. The two tests in question are Test No. 4046 (Nij = 0.94) and Test No. 4047 (Nij = 0.93). The times of maximum Nij were 38.1 ms and 21.4 ms, respectively, before the second stage would be deployed.

Therefore, NHTSA concludes that these "stage 1 only fired" tests are representative of a dual stage inflator in which the 2nd stages fires at or greater than 40 ms.

Table IV-8c
Static Out-of-Position Tests With a 6-Year-Old Child Dummy
Position 2 @ 0 mm Clearance from the Air Bag Module for MY 99

MY 99	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)
Dodge Intrepid	627	**3.39**	**68.8**	39.7
Saturn SL1	76	**2.05**	44.6	**43.4**
Ford Econoline	429	**2.29**	**65.0**	34.3
Acura 3.5RL*	113	0.93	16.0	9.0
Acura 3.5RL**	101	0.83	17.7	3.0
Ford Expedition	131	**2.33**	**85.5**	**45.0**
Toyota Tacoma	246	**2.54**	41.0	18.3
ICPLs	700	≤1.0	60	40

Bold Numbers exceed mandated ICPL values.
* Stages 1 fired and then Stage 2 fired with a 40 ms delay.
** Stage 1 fired only.
Peak Limits for neck compression (C) and tension(T) were not exceeded except as noted.

3-Year-Old Child Dummy Static OOP Tests

The final rule requires the same static OOP deployment tests (Position 1 and 2) as proposed in the SNPRM for the 3-year-old child dummy. The agency did not conduct new, post-August 1998 PEA, Position 1 and 2 tests using the 3- year-old child dummy because of time and resource constraints. The agency believes that if a 6-year-old dummy fails the OOP tests, it is likely that the 3-year-old dummy will also fail. However, if the 6- year-old dummy passes the OOP tests, there is no guarantee the 3-year-old will pass.

B. Full-Scale Vehicle Tests (In-Position)

Belted Test Procedures

56 kmph (35 mph), 0 Deg., Barrier Test, Belted, 50th Percentile Male Dummy

NHTSA examined the 35 mph NCAP data base to examine performance differences due to depowered air bag designs. For a limited set of matched pairs (n=14) as shown in Table IV-9a, MY99 and MY98 responses are not significantly different, except for Nij which was lower by 29 percent and 19 percent for the driver and passenger, respectively, for MY99. Given the similarity of the two model years, NHTSA has combined MY98 and MY99 vehicles into a "redesigned" air bag group for further analysis. For the driver and passenger-side Pass Rates in Table IV-15, for example, MY98 and MY99 have been combined.

Table IV-9a
NCAP Test Results
Average NCAP Test Results for Matched Make/Models
Belted @ 56 kmph (35 mph), 50th Percentile Male Dummy
MY 99 vs MY 98

	HIC_{15}	Nij **	Chest g's	Chest Deflection (mm)	Sample Size (n)
Drivers					
MY 99	446	0.384	50	37	14
MY 98	445	0.542	49	37	15*
Passengers					
MY 99	379	0.429	47	30	14
MY 98	368	0.531	51	33	15
ICPLs 50th	700	1.0	60	63	

All average responses rounded to the nearest whole number.
* MY 98 had two Ford Windstar Tests, whereas MY 99 had one Windstar.
** Peak Limits for neck compression and tension were not exceeded, except for 1998 Dodge Durango where Nij = 1.04 and neck tension failed the peak limit @ 4,448 N.

Comparing MY99 make/models to matched pre-MY98 make/models, as shown in Table IV-9b, indicates that HIC_{15} decreased 14 and 47 percent and chest g's increased slightly by about 3 g's for both the driver and passenger, respectively. Driver and passenger Nij's decreased 26 percent and 42 percent, respectively, from pre-MY98 to MY99. Chest deflection responses were mixed with no clear trend. Table IV-9b is based on matching MY98 and pre-MY98 make/models to MY99 make/models.

Table IV-9b
NCAP Test Results
Average NCAP Test Results for Matched Make/Models
Belted @ 56 kmph (35 mph), 50th Percentile Male Dummy
MY 99 vs Pre-MY 98

Occupant Position	HIC_{15}	Nij *	Chest g's	Chest Deflection (mm)	N
Driver					
MY 99	532.8	0.456	56.04	39.89	5
Pre-MY 98	618.2	0.620	53.62	31.42	5
Passenger					
MY 99	352.8	0.280	50.8	26.2	5
Pre-MY 98	670	0.484	47.72	41.4	5
ICPLs 50^{th}	700	$\leq$1.0	60	63 mm	

* Peak limits for neck compression and tension were not exceeded for any of these tests.

Table IV-9c is based on matching MY98 make/models and pre-MY98 make/models. Table IV-9c shows very little difference between responses for MY98 and pre-MY98 vehicles, on the average, for the belted 56 kmph (35 mph) fixed rigid barrier test condition.

Table IV-9c
NCAP Test Results
Average NCAP Test Results for MY98 vs Pre-MY98 (Matched Make/Models*)
Belted @ 56 kmph (35 mph), 50th Percentile Male Dummy

	HIC_{15}	**Nij ****	**Chest g's**	**Chest Deflection (mm)**	**Sample Size (n)**
Driver					
MY1998 Pre-MY98	376.8 404	0.476 0.462	47.89 49.1	34.55 32.5	34 30-32
Passenger					
MY1998 Pre-MY98	357.2 364.7	0.444 0.445	47.75 49.82	31.38 33.66	33 30-32
ICPLs	1000	1.0	60	63 mm	

* The matched make/models for this table were identified in Appendix A, Table A1., ESV Paper 98-S11-O-01, entitled The Effect of Redesigned Air Bags on Frontal USA NCAP, Park, B.T., Morgan, R.M., and Hackney, J.R., NHTSA/DOT and Lowrie, J.C., Conrad Technologies, Inc.
** Driver & Passenger sides for both MY98 and pre-MY98 had no Nij failures or T/C failures, except on the passenger-side, the 1998 Dodge Ram 1500 had an Nij failure of 1.17 and no T/C failures.

Tables IV-9d and IV-9e compare NCAP results by model year for the driver and passenger, respectively, and show the same comparisons as above based on All Vehicles in the file, rather than matched make/models. Except for Nij, on the average, there has been no substantive change year-to-year in dummy responses. Femur axial loads do not exceed the required ICPL values, except in two or three cases. For the driver and passenger-side, although there are year-to-year fluctuations, there has been a downward trend in Nij from 1996 to 1999. The values in parentheses are Pass Rates (%) used to assess the effect of applying the required 50th percentile male dummy ICPL values to the current fleet. Driver and passenger failures would occur at about the same rate as earlier years. The combined NCAP Pass Rate for MY1996+1997 was 73.5 percent and MY1998 +1999 was 81 percent (combining both driver and passenger Pass Rates).

Table IV-9d
NCAP Test Results
56 kmph (35 mph) NCAP Average Responses & Pass Rates x Model Year
Belted, 50th Percentile Male Dummy
DRIVER (All Vehicles)

MY	HIC_{15}	Nij *	Chest g's	Chest Deflect	Left Femur	Right Femur	N Sample
1996	438.6 (91)	0.498 (97)	51.2 (91)	36.6 (100)	5031 (97)*	4871 (100)	33
1997	461 (94)	0.48 (100)	50.2 (91)	29.9 (100)	4543 (100)	4759 (100)	35
1998	418 (94)	0.51 (98)	49.0 (96)	35.8 (100)	4435 (100)	4231 (100)	51
1999	399 (94)	0.42 (100)	50 (86)	34.5 (100)	4799 (100)	4565 (100)	35
ICPL	700	1.0	60	63	10,000	10,000	

* Peak limits for neck compression and tension were not exceeded except for 1998 Dodge Durango, Nij = 1.04 and peak limit neck tension of 4,448 N

Table IV-9e
NCAP Test Results
56 kmph (35 mph) NCAP Average Responses & Pass Rates X Model Years
Belted, 50th Percentile Male Dummy
PASSENGER (All Vehicles)

MY	HIC_{15}	Nij *	Chest g's	Chest Deflect	Left Femur	Right Femur	N Sample
1996	382.1 (94)	0.546 (94)	52 (82)	36.2 (100)	4687 (100)	4236 (100)	33
1997	461 (94)	0.480 (100)	50 (91)	30 (100)	4543 (100)	4759 (100)	35
1998	364 (94)	0.59 (92)	49.2 (96)	32.9 (100)	4024 (100)	3559 (100)	51
1999	379 (94)	0.392 (100)	48.0 (97)	29.2 (100)	4730 (100)	4086 (100)	35
ICPL	700	1.0	60	63	10,000	10,000	

* Peak limits for neck compression and tension were not exceeded in any of these tests except as noted. 1998 Dodge Durango.

The agency conducted two 56 kmph (35 mph) belted crash tests with the 5th percentile female dummy using a 1988 and 1993 Ford Taurus. As shown in Tables IV-9f, there was a HIC_{15} failure for the 1988 Ford Taurus and an Nij failure for the 1993 Ford Taurus.

Table IV-9f
Test Results
Belted @ 56 kmph (35 mph), 5th Percentile Female Dummy
1988 & 1993 Ford Taurus (NHTSA data)

Occupant Position	HIC_{15}	Nij **	Chest g's	Chest Deflection (mm)	Maximum Femur (N)
Driver					
1988 Taurus*	**1305**	---	52.4	---	---
1993 Taurus*	119	0.54	53.6	35.6	3370R
Passenger					
1988 Taurus	484	---	47.3	---	---
1993 Taurus	508	**1.57**	47.1	33.1	3212R
5th ICPLs	700	≤1.0	60	52 mm	6,800

Bold Numbers indicate test values exceeded the mandated ICPL values for the 5th percentile female dummy.
R indicates right femur had maximum axial load.
* 1988 Ford Taurus did not have air bags, whereas the 1993 Ford Taurus had driver and passenger air bags.
** Maximum values for 1988 Ford Taurus driver-side neck were 203 N (C) and 1,350 N (T). Maximum values for the 1993 Ford Taurus driver-side neck were 918 N (C) and 3,125 N (T). None of the neck independent peak limits were exceeded.

48 kmph (30 mph), 0 Deg., Barrier Test, Belted, 50th Percentile Male Dummy

NHTSA considered a 0-48 kmph (0-30 mph), belted, FRB tests using the 50th percentile male dummy. Based on the 1997-98 NHTSA/ Transport Canada test program, the 48 kmph (30 mph) belted 50th percentile male responses in the August, 1998 PEA consisted of 3 driver (MY98 + pre-MY98 vehicles) and 7 passenger (MY98 + pre-MY98 vehicles) test points with 100 percent Pass Rates. If adjusted to the HIC_{15} and Nij, it is believed the Pass Rates for all responses would remain at 100 percent. Based on the 1998-99 NHTSA/Transport Canada test program using 18 - MY 1999 test vehicles, after applying the new injury criteria and ICPL values, there were no Nij or other response failures. Although compliance data received from GM was incomplete relative to the ICPLs in the final rule (e.g., contained driver and passenger HIC_{36} and chest g's data only) there was a 100 percent Pass Rate for driver and passenger side for a large sample of pre-MY98 and a few MY98 GM make/models. (See Docket No. NHTSA-97-2814-50) These Pass Rates are reflected in Table IV-15, Summary of Pass Rates by Test Procedure.

48 kmph (30 mph), 0 Deg., Barrier Test, Belted 5th Percentile Female Dummy

In addition, NHTSA considered a 0-48 kmph (0-30 mph), belted, FRB test using the 5th percentile female dummy. Table IV-10 shows that for the same test condition as above, the 5th percentile female dummy would experience Nij failures on the driver-side and Nij and chest g's failures on the passenger side.

Table IV-10
48 kmph (30 mph) Belted Barrier, 5th Percentile Female Dummy
MY 98 and 99 Combined, Average Responses

	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)	Sample (n)
Drivers	227 (100%)	0.90 (69%)	46 (100%)	29 (100%)	26
Passengers	239 (100%)	0.57 (96%)	43 (96%)	24 (100%)	26
ICPL	700	≤1.0	60	52	

(   ) Number in parentheses are Pass Rates.
- Peak limits for neck compression and tension were not exceeded in any of these tests, except for the 1998 Mazda 626, passenger-side, failed Nij and neck tension and the 1998 Toyota Tacoma, driver-side, passed Nij but failed neck tension.

Note: Table IV-10 includes new NHTSA/Transport Canada test data. For the passenger side, the air bag did not deploy for either the 1998 Honda Civic or the 1999 Hyundai Accent as these test vehicles were purchased without passenger-side air bags.

40 kmph (25 mph), ODB, 40 Percent Overlap, Belted, 5th Percentile Female Test Dummy

NHTSA is requiring in the final rule a 40 kmph, offset deformable barrier (ODB) test, with 40 percent overlap, using the belted 5th percentile female dummy in the driver and passenger positions. Outboard seat positions are required to be placed in the full-forward position.[5] As shown in Table IV-11, HIC_{15}, chest g's and chest deflection did not exceed the required ICPL values on the driver's side. However, Nij did exceed the required ICPL value of 1.0 on the driver's side (12/16 or 75% for MY99 passed and 8/14 or 57% passed for MY98). On the passenger-side, there were no HIC_{15}, chest g's or chest deflection failures. There was a 100% pass rate for MY99 vehicles based on Nij and an 86% (12/14) pass rate for MY98 vehicles based on Nij.

[5] Commenters argued that the outboard seats should be further back to be consistent with how people actually adjusted their seats in the real-world. They cited the UMTRI study. See "ATD Positioning Based on Driver Posture and Position," Manary, M.A., Reed, M.P., Flannagan, C.A.C., and Schneider, L.W., University of Michigan, Research Institute, SAE Paper #983163. NHTSA tested a vehicle at 48 kmph (30 mph) unbelted, FRB with the seats 3" rearward from the final rule full-forward position, and concluded that overall test stringency was reduced. See the Appendix for crash tests data using a 1999 Acura 3.5 RL and a 2000 Ford Taurus (production model) with seats rearward from full-forward by 3 inches.

Table IV-11
40 kmph (25 mph) ODB, 40% Overlap, Belted, Left, 5th Percentile Female Dummy
Average Responses for MY98 and MY99 Combined
( ) indicates Pass Rate in Percent.

	HIC_{15}	Nij *	Chest g's	Chest Deflection (mm)	Sample size (n)
Driver	182 (100)	0.76 (67)	22 (100)	18 (100)	30
Passenger	114 (100)	0.46 (93)	21 (100)	15 (100)	30
ICPLs	700	1.0	60	52	

NHTSA/Transport Canada cooperative research data.
- Peak limits for driver-side neck compression and tension were not exceeded in any of these tests except for the 1998 Dodge Neon and the 1998 Honda Accord. Peak limits for the passenger-side neck compression and tension were not exceeded in any of these tests..
- Note: On the passenger-side, air bags did not deploy on the 1999 VW Beetle or the 1999 Toyota Camry.

Unbelted Test Procedures

40 kmph (25 Mph) Unbelted Barrier Test, 50th Percentile Male and 5th Percentile Female Dummies

NHTSA considered a 32-40 kmph (20-25 mph), unbelted, FRB test for both the 50th percentile male and 5th percentile female dummy. Tables IV-12a shows that for the 5 vehicles tested, the 50th percentile male and 5th percentile female dummies did not exceed any of the required ICPL values on the driver-side, whereas Table IV-12b shows the only passenger-side mandated ICPL exceeded for both dummies was the Nij. This occurred for the same test vehicle - namely the 1999 Toyota Tacoma.

Table IV-12a
40kmph (25 mph), 0 degree, Unbelted by Dummy Type
DRIVER

MMY	**Dummy Type**	**HIC_{15}**	**Nij***	**Chest g's**	**Chest Deflection (mm)**	**Femur (N) (L or R Leg) Max.**
1999 Dodge Intrepid	50^{th} 5th	193 99	0.288 0.294	40.1 40.5	33.0 32.1	7823R 4674R
1999 Toyota Tacoma	50^{th} 5th	96 238	0.250 0.518	42.8 50.5	46.1 40.5	7281L 4712L
1999 Acura 3.5RL	50^{th}	62	0.207	34.7	35.7	5912L
Confidential MMY	5^{th} **	[ ]	[ ]	[ ]	[ ]	[ ]
Confidential MMY	50^{th} *** 5^{th} ***	[ ] [ ]	[ ] [ ]	[ ] [ ]	[ ] [ ]	[ ] [ ]
ICPLs	50th	700	1.0	60	63	10,000
ICPLs	5th	700	1.0	60	52	6,800

* Peak Limits for neck compression and tension were not exceeded.
** Single stage inflator
*** 1st stage of dual stage inflator.
[ ] confidential data removed.

Table IV-12b
40 kmph (25 mph), 0 degree, Unbelted by Dummy Type
PASSENGER

MMY	Dummy Type	HIC_{15}	Nij *	Chest g's	Chest Deflection (mm)	Femur (N) (L or R Leg) Max.
1999 Dodge Intrepid	50th 5th	83 121	0.294 0.472	48.1 35.1	18.3 4.6	9017L 4324R
1999 Toyota Tacoma	50th 5th	82 143	**1.01** **1.822**	23.4 34.1	15.7 3.7	5236R 5419L
1999 Acura 3.5RL	50th	119	0.406	32.5	17.4	6215R
Confidential MMY	5th**	[ ]	[ ]	[ ]	[ ]	[ ]
Confidential MMY	50th *** 5th***	[ ] [ ]	[ ] [ ]	[ ] [ ]	[ ] [ ]	[ ] [ ]
ICPLs	50th	700	1.0	60	63	10,000
ICPLs	5th	700	1.0	60	52	6,800

* Peak Limits for neck compression and tension were not exceeded.
** Single stage inflator.
*** 1st stage of inflator used.
[ ] confidential data removed.

48 kmph (30 Mph) Unbelted Barrier Test (Matched Pairs MY99 vs Pre-MY98 and Matched Pairs MY98 vs Pre-MY98)

NHTSA considered a 32-48 kmph (20-30 mph), unbelted, fixed rigid barrier test for the 50th and 5th percentile dummies. Pre-MY1998 vehicles were required to meet this test using the 50th percentile male dummy. Tables IV-13a and IV-13b show the average responses from the 30 mph test condition for the 50th percentile male and 5th percentile female dummies, respectively, using the injury criteria ICPLs required in the final rule. For the redesigned air bags, there was little difference between the MY98 and MY99 responses, on the average. For purposes of analysis, MY98 and MY99 vehicles were not necessarily matched make/models.

Table IV-13a
Summary of 48 kmph (30 mph), Unbelted Barrier Tests, 50th Percentile Dummy
Average Responses

	HIC_{15}	Nij *	Chest g's	Chest Deflect	Sample (n)
Drivers					
MY 1999	183	0.291	50.52	42.76	7
MY 1998	205	0.300	47.33	39.96	9*
Passengers					
MY 1999	230	0.360	46.89	15.99	7
MY 1998	187	0.322	50.30	15.0	9*
ICPL	700	1.0	60	63	

Sample size information. There were 7 - MY99 (VRTC) including a 1999 Chevy Blazer. For MY98 there were 7 - MY98 (VRTC) and 2 Ford submissions including a confidential MMY and a 1998 Ford Escort (Non-confidential).
* Peak Limits for neck compression and tension were not exceeded in any of these tests.

48 kmph (30 mph), Unbelted Barrier Test, 5th Percentile Female Dummy

NHTSA considered a 32- 48 kmph (20-30 mph), unbelted, fixed rigid barrier test for the 5th percentile female dummy. The test data in Table IV-13b represents the 48 kmph (30 mph) test condition for 1- MY 1998, 6 - MY 1999 (VRTC), 1 -confidential MMY (VRTC) and 4 - confidential MMYs tested by [ ]. Nij and chest deflection for the driver-side had Pass Rates of 75 percent and 58 percent, respectively. Nij and chest g's for the passenger-side had Pass Rates of 82 percent and 63.6 percent, respectively.

Table IV-13b
Summary of 48 kmph (30 mph), 0 Degrees, Unbelted Barrier, 5th Percentile Female Dummy
Average Responses for MY98-2000 Vehicles
( ) indicate Pass Rate %

	HIC_{15}	Nij *	Chest g's	Chest (mm) Deflection	Sample size (n)
Driver	125 (100)	0.720 (75)	46.37 (100)	45.03 (58.33)	12
Passenger	278 (100)	0.810 (82)	52.66 (63.6)	10.87 (100)	11
5th ICPLs	700	1.0	60	52	

* Peak Limits for neck compression and tension were not exceeded for any of the tests.
The driver sample (n =12) includes 1998 Ford Taurus from the August, 1998 PEA, 1999 Saturn SL1, 1999 Dodge Intrepid, 1999 Toyota Tacoma, 1999 Acura RL, 1999 Ford Econoline, 1999 Chevy Blazer and 5 - confidential MMY tests conducted by [ ] are included in this table. The passenger sample (n=11) has 4 of the above confidential MMY tests. The confidential MMYs were pre-production prototypes.

48 kmph (30 Mph), +/-30 Degree (L or R) Oblique, Unbelted Test, 50th Percentile Male & 5th Percentile Female Dummies

NHTSA considered a test speed of 32-48 kmph (20-30 mph), for a +/- 30 degree (L or R) oblique unbelted test procedure for the 50th percentile dummy. This test at 48 kmph (30 mph) is already required by FMVSS 208 using the 50th percentile male dummy, except that HIC_{15} and Nij are being required in the subject final rule. Oblique tests with the 5th percentile female dummy were not considered in the final rule, but response data is shown in Tables IV-14a and IV-14b for comparison purposes. As shown in Tables IV-14a and IV-14b, driver and passenger responses were benign for the 50th percentile male dummy with a 100 Pass Rate for the 30 mph, 30 degree oblique, unbelted test.

For the case of the 50th percentile male dummy, all 4 vehicles studied passed both driver and passenger ICPL requirements. [Similarly, driver and passenger responses were benign for the 5th percentile female dummy, except for the driver-side Nij for the 1999 Dodge Intrepid resulting in a 75 percent Pass Rate (considering all 4 test vehicles) for the 30 mph, 30 degree oblique, unbelted test. The maximum femur axial load occurred predominantly on the impacted or near-side and did not exceed the required ICPLs in these tests. It is difficult to detect any significant differences in stringency between left or right side impacts for either dummy size. For the same MMY test vehicle, the impact-side dummy appears to have the higher responses, but responses were mixed.

Table IV-14a
48 kmph (30 Mph), +/-30 Degree Oblique (L or R), Unbelted Barrier Test
50th Percentile Male & 5th Percentile Female Dummies
DRIVER

	Impact Direction	**ATD Size**	**HIC_{15}**	**Nij ***	**Chest g's**	**Chest Deflection (mm)**	**Maximum Femur (N) (L or R leg)**
Confidential MMY	Right	50th **	[ ]	[ ]	[ ]	[ ]	[ ]
1999 Dodge Intrepid	Right	50th 5th	53 107	0.282 0.379	34.3 36.7	24 32	5624R 5644R
1999 Dodge Intrepid	Left	50th 5th	210 86	0.272 **1.514**	43.0 44.52	32.1 27.6	5666L 4249R
Confidential MMY	Right	50th *** 5th ***	[ ] [ ]	[ ] [ ]	[ ] [ ]	[ ] [ ]	[ ] [ ]
ICPLs		50th	700	1.0	60	63	10,000
ICPLs		5th	700	1.0	60	52	6,800

* Peak Limits for neck compression and tension were not exceeded for any of these tests.
** Single stage inflator.
*** Only the 1st stage of a dual stage inflator fired.
[ ] confidential data removed.

Table IV-14b
48 kmph (30 mph), +/-30 Degree Oblique, Unbelted 50^{th} Percentile Male & 5^{th} Percentile Female Dummies
PASSENGER

	Impact Direction	ATD Size	HIC_{15}	Nij *	Chest g's	Chest Deflection (mm)	Maximum Femur (N) (L or R leg)
Confidential MMY	Right	50^{th} **	[ ]	[ ]	[ ]	[ ]	[ ]
1999 Dodge Intrepid	Right	50^{th} 5th	233 121	0.326 0.275	34.7 29.2	6.10 5.2	5180L 3658R
1999 Dodge Intrepid	Left	50^{th} 5th	288 123	0.321 0.410	45.5 51.0	18.9 5.82	6267L 5397L
Confidential MMY	Right	50^{th}*** 5^{th} ***	[ ] [ ]	[ ] [ ]	[ ] [ ]	[ ] [ ]	[ ] [ ]
ICPLs		50th	700	1.0	60	63	10,000
ICPLs		5th	700	1.0	60	52	6,800

* Peak Limits for neck compression and tension were not exceeded in any of these tests.
** Single stage inflator.
*** Only the 1st stage of a dual stage inflator was fired.
[ ] confidential data removed.

Given the range of dummy response variability observed in other crash tests, these test vehicles would still be expected to pass if typical variations occurred as in other tests. This appears to be a very benign test because (1) an oblique impact angle involves a lot of crushed soft sheet metal and a soft crash pulse and (2) the "fire time" was very timely, similar to a full frontal fixed rigid barrier. General Motors provided 48 kmph (30 mph), +/-30 degree oblique (L+R), unbelted, fixed rigid barrier 50^{th} percentile male dummy compliance data, but this was an incomplete data set (e.g., included driver and passenger HIC_{36} and chest g's only). The GM data was predominantly pre-MY98 and a few MY98 make/models. (See Docket No. NHTSA-97-2814-50)

C. Summary of Pass Rates by Test Procedure

Table IV-15 summarizes the Pass Rates for each of the full-scale vehicle test procedures and the static OOP test procedures either considered in development of the final rule or required in the final rule. The agency combined MY98 and MY99 vehicles together in order to calculate Pass Rates. For the 25 mph unbelted test Pass Rate, 50^{th} percentile male and 5^{th} percentile female, MY1999 (n=4) test results and 1- confidential MMY pre-production prototype test results were combined. Similarly, for the 30 mph barrier test Pass Rate, using the unbelted 5^{th} percentile female dummy, 1 - MY1998 was combined with 7- MY1999 vehicles and 5 confidential MMY vehicles for a total sample of 12 on the driver-side and 11 on the passenger-side. The confidential MMY in these tests were pre-production prototypes. Also, for the 30 mph, 30 degree oblique, unbelted 50^{th} percentile male crash test Pass Rate, several confidential make/model/year vehicles were combined with NHTSA tests. Some of the pre-MY98 and MY98+99 Pass Rates shown in Table IV-15 were determined using General Motors FMVSS 208 compliance data which was released to Docket No. NHTSA-97-2814-50. The GM data set did not contain Nij. The Pass Rates are used in Chapters VI, Benefits, and VII, Cost and Leadtime, to calculate benefits and costs.

Table IV-15
Summary of PASS RATES by Test Procedure

Test Procedure	Pre-MY98 Pass Rate	MY98+99 Pass Rate	Source of Data	Remarks
OOP 5th Percentile Female Driver	HIC_{15} 700, Nij =1, 60g's, 52mm	HIC_{15} 700, Nij =1, 60g's, 52mm		
	25% (1/4)	36.4% (4/11)	VRTC tests, Pre-MY98, MY98 & MY99: Position 1 and Position 2	Pre-MY98 & MY98 all fail Nij MY99- 2/6 fail Nij
Static OOP CRABI*, **	HIC_{15} 390, Nij ≤1, 50 g's, 30 mm*	HIC_{15} 390, Nij ≤1, 50 g's, 30 mm*		
	0% in sleds. (a.) (No data in vehicles)	100% (n=1) (b.)	VRTC 213 sled tests This replaces Table IV-10, 11 & 12 in 8/98 PEA. See Docket 99-5156-6. Static OOP Deployment test. n=1	(a.) HIC_{15} & Nij failures in sled tests. *** (b.) No ICPL failures in Low Risk Deploy Test. ****
OOP 6-Year-Old Child Passenger	HIC_{15} 700, Nij ≤1, 60 g's, 40 mm	HIC_{15} 700, Nij ≤1, 60 g's, 40 mm		
	0%	7.69% (1/13)	VRTC Pre-MY98 MY 98 + MY 99 Tests Position 1 + Position 2	MY99 Nij, chest g & deflect. failures. MY98 HIC_{15}, chest g, deflect & Nij failures.
35 mph, belted, 50th Percentile Male	HIC_{15} 700, Nij ≤1, 60 g's, 63 mm	HIC_{15} 700, Nij ≤1, 60 g's, 63 mm		
Driver	88% (70/80)	86.9% (73/84)	1996-1999 NCAP data	HIC_{15}, Nij, & chest g's failures. *****
Passenger	83.9% (68/81)	89.3% (75/84)	1996-1999 NCAP data	HIC_{15}, Nij, & chest g's failures. *****
35 mph, belted, 5th Percentile Female	HIC_{15} 700, Nij ≤1, 60 g's, 52 mm	HIC_{15} 700, Nij ≤1, 60 g's, 52 mm		
Driver	50% (1/2)	N.D.	1988 Ford Taurus, no air bags & 1993 Ford Taurus with air bags. (VRTC)	1988 Ford Taurus failed HIC_{15} Incomplete data
Passenger	50% (1/2)	N.D.	1988 Ford Taurus, no air bags & 1993 Ford Taurus with air bags. (VRTC)	1993 Ford Taurus failed Nij Incomplete data
30 mph, belted, 50th Percentile Male	HIC_{15} 700, Nij ≤1, 60 g's, 63 mm	HIC_{15} 700, Nij ≤1, 60 g's, 63 mm		
Driver	100 %	100%	n=1, Pre-MY98, 1996 Dodge Caravan n=18 MY1999 T.C. data GM data 1990-98	No failures
Passenger	100%	100%	Pre-MY98 Table B-15 PEA June, 1998. n=18, MY1999 T.C. data GM data 1990-98	No failures
30 mph, belted 5th Percentile Female	HIC_{15} 700, Nij ≤1, 60 g's, 52 mm	HIC_{15} 700, Nij ≤1, 60 g's, 52 mm		
Driver	45.5% (10/22)	65.4% (17/26)	NHTSA/ Transport Canada (Old + New)	Pre-MY98 Nij failures MY 98+99 Nij failures
Passenger	64.3% (9/14)	92.3% (24/26)	NHTSA/ Transport Canada	No MY99 failures MY98 - 2 Nij& 1 chest g.

25 mph, ODB belted 5th Percentile Female	HIC_{15} 700, Nij ≤ 1, 60 g's, 52 mm	HIC_{15} 700, Nij ≤ 1, 60 g's, 52 mm		
Driver	36.4% (4/11)	67% (20/30)	NHTSA/ Transport Canada (97+98) (98+99)	Nij only problem. Left- side impacts n=30
Passenger	71.43% (5/7)	93% (28/30)	NHTSA/ Transport Canada (97+98) (98+99)	Nij only problem. Left-side impacts n=30.
25 mph, Unbelted Barrier Tests	50th - HIC_{15} 700, Nij ≤ 1, 60 g's, 63 mm 5th - HIC_{15} 700, Nij ≤ 1, 60 g's, 52 mm	50th - HIC_{15} 700, Nij ≤ 1 60 g's, 63mm 5th - HIC_{15} 700, Nij ≤ 1, 60 g's, 52 mm		
Driver 50th Male	N.D.	100% (4/4)	n=4 3 VRTC, 1 confid.	No Failures
Driver 5th Female	N.D.	100% (4/4)	n=4 2 VRTC, 2 confid.	No Failures
Passenger 50th Male	N.D.	75% (3/4)	n=4 3 VRTC, 1 confid.	1 Nij failure Tacoma
Passenger 5th Female	N.D.	75% (3/4)	n=4 2 VRTC, 2 confid.	1 Nij failure Tacoma
30 mph , unbelted 50th Percentile Male	HIC_{15} 700, Nij ≤ 1, 60 g's, 63mm	HIC_{15} 700, Nij ≤ 1, 60 g's, 63mm		
Driver	100% HIC only (Nij not available, not instrumented)	88% (14/16)	VRTC 7-MY 1999 VRTC 7-MY 1998 1 - MY98 Ford Escort 1 - Confidential MMY	1999 Acura Driver Femur failure (13,349 N). Chevy Blazer chest g failure (63.06 g's).
Passenger	100% HIC only (Nij not available, not instrumented)	94% (15/16)	VRTC 7-MY 1999 VRTC 7-MY 1998 1- MY98 Ford Escort 1- Confidential MMY	1998 Dodge Neon failed Chest g's (61.4 g's)
30 Mph, Unbelted 5th Percentile Female	HIC_{15} 700, Nij ≤ 1, 60 g's, 52 mm	HIC_{15} 700, Nij ≤ 1, 60 g's, 52 mm		
Driver	Not available	42% (5/12)	n=1 MY98, n=6 MY99, n=5 Confidential MMY	3 Nij & 5 chest deflection failures
Passenger	Not available	45.5% (5/11)	n=1 MY98, n=6 MY99, n=4 - Confidential MMY	2 Nij & 4 chest g's failures
30 mph, unbelted, 30 deg oblique 50th Percentile Male	HIC_{15} =700, Nij ≤ 1, 60 g's, 63 mm	HIC_{15} =700, Nij ≤ 1, 60 g's, 63 mm		
Driver	100%	100%	GM compliance data 1990-98, see Table IV-14a (NHTSA+Ford)	No failures
Passenger	100%	100%	GM compliance data 1990-98, see Table IV-14b (NHTSA+Ford)	No failures

Table IV-15 Footnotes are as follows: T.C. = Transport Canada, N.D. - No data available at this time. *CRABI dummy cannot measure deflection. **Suppression or low risk test option in the final rule. *** 1997 Ford Taurus and 1998 Ford Explorer was full power inflator technology, **** 1st stage of experimental inflator from a confidential MMY, ***** No deflection failures occurred in these NCAP files and there were two femur load failures (1) 1996 Dodge Ram 250 Van and (2) 1998 Ford Escort.

D. Test Procedure Stringency

Static Test Procedures, Out-of-Position

a. 12-Month-Old Infant (CRABI) Low Deployment Test

NHTSA conducted one (n=1) static low risk deployment test using the 12-month-old infant (CRABI) dummy which Passed all the mandated injury criteria.

b. Static OOP Test (Driver-Side) - Position 1 vs Position 2 Stringency based the 5th Percentile Female Dummy

Considering that the dummy injury responses are equally weighted, and the limited number of data points available, OOP Position 1 would appear to be more stringent than OOP Position 2 based on Nij and HIC_{15}, whereas Position 2 would appear to be more stringent than Position 1 based on chest g's and chest deflection. The data supports the idea that these tests are complementary, namely - OOP Position 1 is more of a "worst case" head/neck impact condition, while OOP Position 2 is more of a "worst case" chest impact condition. The agency has a limited number of data points because of resource and manpower constraints.

c. Static OOP Test (Passenger-Side) - Position 1 vs Position 2 Stringency based the 6-Year-Old Child Dummy

Recognizing the limited number of data points, OOP Position 2 would appear to be more stringent than Position 1 based on the magnitude of HIC_{15}, Nij and chest g's responses.

d. Static OOP Test (Passenger-Side) - Position 1 vs Position 2 Stringency based the 3-Year-Old Child Dummy

This was discussed earlier. Due to limited time and resources, the agency did not conduct any 3-year-old child dummy static OOP tests.

Dynamic Test Procedures, In-Position

a. Left vs Right 48 kmph (30 mph), 30 degree Oblique, Unbelted Test Stringency

NHTSA considered (both left and right side) 48 kmph (30 mph), +/-30 degree oblique unbelted impact tests using the 50^{th} percentile male dummy. The following GM 208 compliance data compares the two test directions for a limited set of responses. Table IV-16a shows a few selected GM vehicles tested both in the left and right directions, whereas Table 16b compares All Vehicles in the GM file.

Table IV-16a
L vs R, 48 kmph (30 mph), 30 degree Oblique Impacts, Unbelted, 50^{th} Percentile Male Dummy, Average Responses (n=3) Pre-MY98 Make/Models
GM 208 Compliance Data

	Driver HIC_{36}	Driver Chest g's	Passenger HIC_{36}	Passenger Chest g's	n
Left-Side Impact Point	217	35.7	143	30.6	3
Right-Side Impact Point	297	34	293	35	3

* The sample (n=3) consisted of a 1997 Eldorado/Seville, a 1995-97 Buick Riviera, and a 1995-97 Oldsmobile Aurora. Docket No. NHTSA-97-2814-50

Although the number of tests are limited, and recognizing that the data available reflects pre-MY98 make/models, there does not appear to be any significant difference between a left (L) or right (R) 48 kmph (30 mph), 30 degree oblique <u>unbelted</u> impacts when using the 50th percentile male dummy.

Table IV-16b
L vs R, 48 kmph (30 mph), 30 degree Oblique Impacts, Unbelted, 50th Percentile Male Dummy, Average Responses - All GM Make/Models, MY1990-98
GM 208 Compliance Data

	Driver HIC_{36}	**Driver Chest g's**	**Passenger HIC_{36}**	**Passenger Chest g's**	**n**
Left-Side Impact Point	266.5	35.38	184.8	36.06	34-75
Right-Side Impact Point	156.3	34.49	191.7	35.09	41-62

* Different make/model/year GM test vehicles made up the Left-side and Right-side impact data sets although there was some overlap in a few cases. Docket No. NHTSA-97-2814-50.

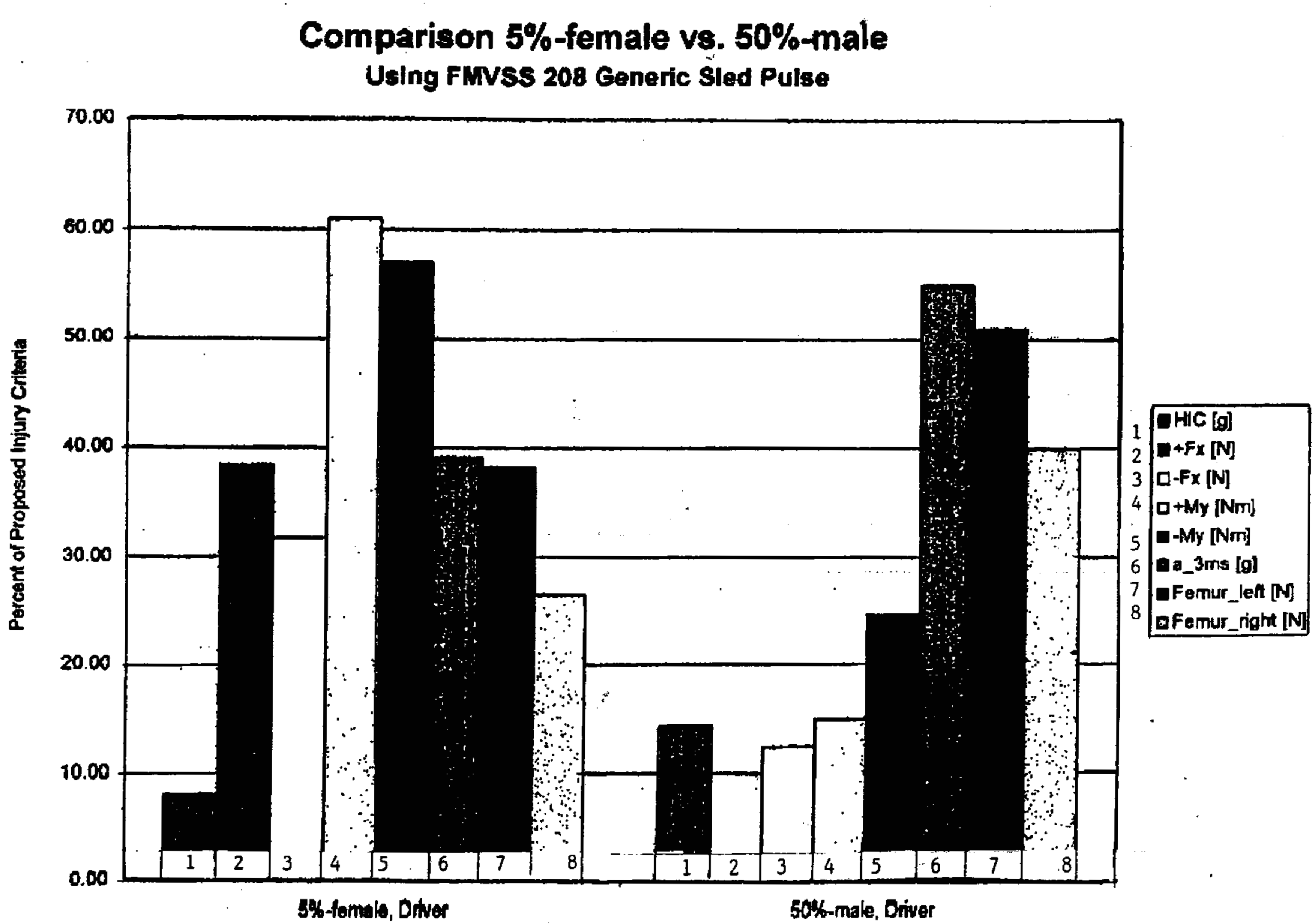
Although the number of tests are limited, and the data available reflects Pre-MY98 make/ models, there does not appear to be any significant difference between a left (L) or right (R) 30 mph, 30 degree oblique unbelted impact, when using the 50th percentile male dummy based on <u>All Vehicles</u>. On the average, all responses for the left-side impacts were numerically higher than the right-side oblique impacts. This suggests that the left-side unbelted oblique impact condition might be slightly more stringent, on the average, compared to the right-side oblique impact condition. However, because left-side and right-side impact make/models were not necessarily matched, the higher numerical values could be due to make/model differences.

50th vs 5th Percentile Dummy Dynamic and Compliance Equivalence

Sled Tests

BMW provided a comparison of 50th and 5th percentile dummy responses based on the FMVSS 208 S13 sled test. (See Docket No. 98-4405-59) Figure IV-1 shows a good comparison of the dynamic responses of both dummies under identical, low variability test conditions. This bar chart compares the dynamic equivalence of the two dummies. For example, the 5th percentile dummy is more vulnerable in the areas of fore/aft neck shear and neck moments (extension and flexion) compared to the 50th percentile dummy, whereas the 50th percentile male dummy is more vulnerable in the chest g's area for the same test condition.

FIGURE IV-1



Source: BMW Docket No. 98-4405-59, 12/15/98

Full-Scale Vehicle Tests: Dummy Response Comparison

30 mph, 0 Degree Fixed Rigid Barrier, Unbelted Test Condition

Tables IV-17a and IV-17b compare the responses of the 50^{th} percentile male and 5^{th} percentile female dummies for the 30 mph, 0 degree impact, unbelted, fixed rigid barrier test condition using 1999 Saturn SL and 1999 Chevy Blazer test vehicles. The Saturn driver and passenger responses for both dummies were very similar. Using either dummy and the new required injury criteria and associated ICPLs, the subject vehicle would have passed the test. For the Chevy Blazer (Table IV-17b), although the responses for both dummies were very similar, the use of either dummy would have led to non-compliance as the driver chest g's using the 50^{th} percentile dummy exceeded (@ 63.06 g's) the required ICPL value (60 g's) and the passenger Nij using the 5^{th} percentile dummy exceeded (@1.178) the required ICPL value (1.0).

Table IV-17a

50th Percentile Male vs 5th Percentile Female Dummies

48 kmph (30 mph), 0 Degree Fixed Rigid Barrier, Unbelted Test

Model Year	Make/ Model	Occupant Position/ ATD	HIC_{15}	Nij *	Chest g's	Chest Deflection	Max. Femur (N)**
1999	Saturn SL1	**Driver** 50th	128	0.330	36.8	46.8	5288(L)
1999	Saturn SL1	**Driver** 5th	106	0.340	37.0	31.1	3566(L)
1999	Saturn SL1	**Passenger** 50th	200	0.314	40.2	9.2	6374(L)
1999	Saturn SL1	**Passenger** 5th	276	0.619	44.7	15.2	3259(R)

* Peak Limits for neck compression and tension were not exceeded for any of these tests.

** Maximum Femur (Left or Right leg) indicated by parentheses.

Table IV-17b
50th Percentile Male vs 5th Percentile Female Dummies
48 kmph (30 mph), 0 Degree Fixed Rigid Barrier, Unbelted Test

Model Year	Make/ Model	Occupant Position/ ATD	HIC_{15}	Nij *	Chest g's	Chest Deflection	Max. Femur (N)*
1999	Chevy Blazer	**Driver** 50th	153	0.335	**63.06**	62.35	8504R
1999	Chevy Blazer	**Driver** 5th	106	0.323	44.47	40.32	6131L
1999	Chevy Blazer	**Passenger** 50th	289	0.339	51.76	15.07	6019L
1999	Chevy Blazer	**Passenger** 5th	255	**1.178**	45.7	10.92	4080R

* Peak Limits for neck compression and tension were not exceed in any of these tests.
** Maximum Femur (Left or Right leg) indicated by parentheses.
Bold Numbers indicate that the required **ICPL** values were exceeded.

48 kmph (30 mph), 30 Degree Oblique (L), Unbelted, Test Condition

As shown in Tables IV-14a and IV-14b, for the 1999 Dodge Intrepid (Left Impact Direction), the responses of the 50th and 5th percentile dummies were very similar, except for driver-side Nij failure for the 5th percentile female dummy. The 50th percentile male dummy Nij was 0.272, whereas the 5th percentile female dummy Nij was 1.514. Passenger-side responses were very similar and did not exceed any of the applicable ICPLs. Therefore, for this test vehicle, introduction of the 5th percentile female dummy and concomitant ICPLs would result in a test failure, whereas passage would have occurred with the 50th percentile male dummy alone. [NOTE: The 5th percentile female dummy is included here for comparison purpose only and is not a required test in the final rule.]

Overall, the two dummies appear to be dynamically equivalent as they have very similar responses for the same dynamic test conditions and appear to be equivalent from a compliance point of view. However, there were several cases where the dummies were not equivalent from a compliance point of view. In each of those cases, the 5th percentile female dummy was more vulnerable to failure than the 50th percentile male dummy.

Final Rule Nij vs SNPRM Nij

For the in-position, 50th percentile male and 5th percentile female high speed crash tests, the Nij values of the final rule are generally lower than the SNPRM values because the critical neck tension and compression intercept values have been increased. The affected constants appear in the denominator of the Nij formula. Similarly, for the 5th percentile female dummy OOP tests, the Nij values in the final rule are lower compared to the SNPRM. However, for the 6-year-old child dummy out-of-position tests, the Nij values in the final rule are slightly higher compared to the SNPRM. The Nij values for the 6-year-old OOP are slightly higher because the agency used a critical extension moment intercept value of 37 N-m as opposed to the 39 N-m used in the SNPRM. The affected constants appear in the denominator of the Nij formula.

The final rule requires that neck peak limits can not be exceeded as well as Nij must be less than or equal to 1.0. As a rule, Nij failures are highly correlated with neck tension (T) failures. Neck compression (C) failures are very rare events. The agency found several cases where Nij passed the test, but failed the neck tension peak limit. These cases include the following:

1. 1999 Saturn SL1, 6-year-old, OOP Position 1, Nij = 0.93 and neck T = 1,799 N,
2. 1997 Toyota RAV4, 5th percentile female dummy, 30 mph, belted, passenger-side, Nij = 0.91 and neck T = 2,961 N,
3. 1998 Toyota Tacoma, 5th percentile female dummy, 30 mph, belted, driver-side Nij = 0.77 and neck T = 2,726 N, and
4. 1996 Ford Taurus, 5th percentile female, OOP Position 1, Nij = 0.91, neck T = 2,595 N.

The reason this occurs is that the Nij value can be located above the horizontal neck tension independent peak limit line, but it can be located within the vertical apex of the Kite shaped Nij =1.0 boundary line. There is also a single case where Nij failed and both neck compression and neck tension failed the peak limits. For the 1998 Honda Accord, 6-year-old OOP Position 1 test, Nij (N_{tc}) = 2.11, neck T = 2,591 N and neck C = 1,899 N. These maximum T and C values occurred at different times in the crash event.

V. TECHNOLOGY OPTIONS AND ANALYSES

A. Discussion of Technologies

The agency knows of a variety of technologies that could be implemented by the manufacturers to meet the various tests. This section discusses those technologies. Based on discussions with vehicle manufacturers, the agency believes many of the technologies could and will be used to meet the variety of tests.

The performance requirements of FMVSS 208 already provide considerable design flexibility for manufacturers. The standard's occupant requirements are performance requirements and do not specify the design of an air bag. Instead, vehicles must meet specific injury criteria performance limits (ICPL) measured on test dummies during barrier crash tests, for example at speeds up to and including 30 mph at any angle up to 30 degrees in either direction from perpendicular, or meet the ICPL in an alternative generic sled test.

While the standard requires air bags to provide protection for properly positioned occupants (belted and unbelted) in relatively severe crashes, and air bags must deploy quickly to provide such protection, the standard does not require the same speed of deployment in the presence of out-of-position occupants, or even any deployment at all. The standard allows for the use of dual or multiple level inflator systems and automatic cut-off devices for out-of-position occupants and rear facing infant restraints. The agency notes that dual level inflator systems can provide the equivalent of a softer air bag for lower speed crashes and/or when occupants are close to the air bag or are belted, and a faster, more powerful air bag to provide protection in severe crashes and/or in crashes with unbelted occupants. The agency also notes that FMVSS 208 does not specify a crash threshold at which air bags must deploy, and that thresholds could be raised substantially for most current vehicles while still meeting the requirements of FMVSS 208. Injury protection at lower speeds can be and has been accomplished with a softer, compliant interior design.

B. Out-of-Position Test Technologies

There are essentially two ways to meet the out-of-position tests: **suppression** of the air bag (the air bag is turned off), or a **low risk deployment** of the air bag (dummy test results meet the injury criteria when the air bag is deployed with the dummy on or close to the air bag).

1. Suppression of the Air Bag

Using information supplied by various sensors inside the vehicle, a determination would be made by the vehicle's computer controlled occupant protection system that the air bag should not deploy.

2. Low Risk Deployment

Low risk deployment of the air bag might be accomplished either by having a single-stage air bag system that is designed to not injure out-of-position occupants or by having two or more stages of air bag deployment. In a dual-stage or multi-stage system, the lowest level of deployment would be a low risk deployment, while higher levels of deployment would be used when the occupant needs more protection. The agency has tested driver air bags that can meet the low risk deployment criteria as a single-stage air bag (4 of 11 MY 98/99 vehicles and 1 of 4 pre-MY 98 vehicles tested met the criteria). On the passenger side, only 1 of 13 vehicle tests met the 6 year old criteria. This vehicle was the only one tested with a dual-stage air bag and it passed the out-of-position tests at the lower level deployment of a dual-stage air bag. This vehicle was not tested using the 3 year old dummy.

It would appear that meeting the injury criteria on the driver side will be easier than meeting the injury criteria on the passenger side using low risk deployment air bags. There are several reasons for this: 1) The current driver side air bags are not as aggressive as passenger side air bags. The driver is usually directly behind the steering column and there is less distance from the steering wheel to the driver than from the instrument panel to the right front passenger. Thus, the air bag for the driver side is smaller and needs less energy to inflate than the right front passenger bag. There is also the possibility of recessing the air bag back from the plane of the steering wheel, allowing it to start to open before contacting the driver. 2) A small child is not as tolerable to injury as an adult, thus the ICPLs are lower on the small dummies (e.g., the 3 year old dummy) than on the 5th percentile female dummy used in the driver position.

Sensor Technologies

The sensor technologies being investigated to supply information to the computer logic to determine when and how severely to inflate air bags can be divided into the following categories:

1) crash severity sensors

2) occupant weight sensors

3) occupant proximity and motion sensors

4) safety belt use status sensors

5) seat position sensors

3. Crash Severity Sensors

Two general types of crash severity sensors are in use today. The design goal is to make an early determination of the crash forces transmitted to the occupant compartment, while ignoring forces that will not require air bag deployment. The trend in the early 90's was towards a system with a single point crash sensor, an electronic accelerometer located in or around the passenger compartment.

The second type of system is the more expensive multi-point sensing system. In this system, electromechanical switches are used in combinations of discriminating sensors and secondary sensors located at different points in the forward part of the vehicle. The discriminating sensors located in the front crush zone activate at a specified change in velocity, while the secondary sensor located further back are used to prevent unwanted air bag deployments from localized damage. Several years ago, most models had multi-point sensing systems. Whether a vehicle needs a multi-point sensing system or can use a single point crash sensor system depends on a variety of factors, including the vehicle crush characteristics over a wide range of crash pulses.

The offset deformable fixed barrier test may force some manufacturers into using a multi-point sensing system. This system may include a combination of electronic (single point compartment sensors) and electromechanical (crush zone) sensors. Multi-point sensing may be necessary for dual-level inflation in order to get more information about the severity of the collision.

Current air bag systems use the output from the crash severity sensors to determine when to deploy and when not to deploy the air bag. Most systems are set to have a no-fire zone at 8 mph or less and to have an all-fire zone with a change in velocity (delta V) of 15 mph or more. This decision speed is called a threshold. Some manufacturers currently are using different thresholds for unbelted and belted occupants. A higher threshold is used for belted occupants (all fire at 18 mph or higher), since belted occupants are at a lower risk of injury. One of the possible technologies for meeting the up to 25 mph offset test, which has a belted occupant, would be to raise the air bag deployment threshold to have no deployment in this long duration crash pulse test. To make this decision, the manufacturers would attempt to determine the risk of injury at different speeds with and without the air bag for belted and unbelted occupants in particular make/models. The agency has crash tested one vehicle (Chevrolet S-10 pickup) with no air bag at 15 mph and found that the unbelted 3-year-old passenger dummy did not pass the neck criteria. It is not known whether other passive interior changes, such as adding padding, could be used to lower injury risk for unrestrained occupants if the air bag firing threshold were raised.

Designers must consider how a change in the sensors would affect the timing of deployments for higher speed crashes, before raising the lower threshold. Some manufacturers have already increased their deployment thresholds, particularly in other countries that have very high belt usage. A high threshold may be easier to accomplish in particular vehicles because of their design and crash pulse than in other vehicles.

4. Occupant Weight and Pattern Recognition Sensors

The purpose of a weight sensor is to measure the size of an occupant by measuring forces on the seat. Some systems also measure the distribution of the occupant on the seat to improve the ability to classify occupants and their location on the seat. Recent technology developments include measuring the pattern of pressure distribution on the seat or deflection of the seat and using this pattern to identify whether there is a child restraint on the seat, the size of the occupant, and whether the occupant is sitting back in the seat or up on the front edge.

Three types of weight sensors are being developed. The first uses resistive strain gauges or load cells, typically near the base of the seat, which indirectly lead to a measurement of weight. The agency does not have a cost estimate for these systems, and is not sure how they could work for a bench seat, but it is believed that they could be less costly than the mat type system for a bucket seat. The second type is a "bladder" type system within the seat cushion that measures pressure. However, neither of these systems have received as much attention as the mat-type electronic pressure sensor system because they cannot provide as much information about the occupant as the pattern recognition technology being developed.

The third type of system is a weight sensing electronic mat. The electronic mat, which is installed in the seat cushion, is an array of conductive polymeric sensors which change resistance under load. The initial Mercedes-Benz mat was designed to deactivate the air bag when the seat was empty or had a low weight in it. The nominal deactivation threshold was 26 pounds.

The heaviest child dummy in the final rule is the 6-year-old, that weighs about 54 pounds with all the instrumentation. Thus, the final rule could be met by a weight sensor that distinguishes between the 6 year-old dummy and a 5th percentile female dummy at 107.8 pounds.

Pattern recognition sensors evaluate the impression made by an occupant, child restraint, or object on the seat cushion to make a determination about occupant presence and overall size and position of the occupant. They are often combined with a weight sensor to get better information.

5. Occupant Presence, Proximity, and Motion Sensors

A wide variety of sensing technologies have been explored by suppliers and manufacturers to detect occupant presence, proximity, and in the case of child restraints, seat position. Technologies being investigated include passive and active infrared, superaural acoustic, capacitive (electric field), radar, and visible imaging. A passenger side system could statically make a determination of a RFCSS, a 3 year old dummy, and a 6 year old dummy where the air bag should be turned off and distinguish these occupants from a 5th percentile female dummy where the air bag should be on. In general, the suppliers and manufacturers are working towardsz a dynamic system updating information every 10 ms or so to make decisions. A dynamic system theoretically can determine that an occupant has moved too close to the air bag (out-of-position), either through pre-impact braking or the movement caused by more minor initial impacts in a multiple impact crash, and is quick enough to turn off the air bag or determine that a low-risk deployment is appropriate. Static detection systems are reportedly going to be used if dynamic systems are not developed in time. However, it is more likely that these more expensive systems with occupant presence and proximity sensing will be used as part of a dynamic system in the future. It may well be that two types of systems may be used in conjunction with each other to eliminate to the extent possible the potential for false readings.

Capacitive (Electric Field): This technology senses the dielectric loading of an oscillating electric field set up between sets of electrodes. An electrical field can be used to measure an array of displacement currents. Fixed electrodes can all be installed in the seat cushion or seat back, or they can be installed in the seat and the instrument panel and headliner, each of which can generate an electric field and measure the loading currents out of the electrode and the received currents from the other electrodes. When a person is in the seat, the person screens the electric field because of the body's high internal conductivity, and thereby shunts the displacement current to other receiving electrodes and to the automobile ground return. The electrical characteristics are then interpreted to determine the presence and size of the occupant in the seat. This type of system is currently in production.

Passive Infrared Systems: These systems depend on the detection of infrared emission from the skin and face of occupants. The amount of energy emitted is proportional to the 4th power of its absolute temperature. A coarse resolution optical system is required to focus the seat environment onto an infrared sensing array. Infrared emissions must be correlated with conditions of occupancy. Care must be taken so that the system is not fooled by blankets, which are sometimes thrown completely over infants in rear-facing child seats. Infrared emissions overload can come from cigarettes, heat soaked vehicle interiors, hot food and beverages and sunlight. These occurrences must be designed around or a second type of sensing system must be used to assure no false readings.

Ultrasonic Sensing, Non-imaging Pattern Recognition: These systems use a broad beam of pulsed ultrasonic waves to illuminate the air bag deployment zone and the seat occupancy zone. These systems attempt to recognize when a seat is unoccupied or the location of the occupant, adult or child, whether still or moving towards the instrument panel. The principle of ultrasonics is based on sonar technology, pulsing a brief, inaudible signal, timing its return, and calculating the distance. Multiple transducers may be placed in the instrument panel, overhead console and trim around the A-pillar, B-pillar or side roof rail. Multiple transducers can be used to obtain the optimal line of sight to the areas of interest, and to recognize and track the movement of the occupant. The ultrasonic system has been designed based on priority inputs and time compression within close target proximity to adequately capture the fact that unrestrained occupants may start into a crash normally seated but, due to pre-crash braking or slow onset types of crashes, may be just moving into close proximity to the instrument panel at the time of the firing command.

Ranging Systems: These systems rely on bouncing a beam of waves off an object and measuring their transit time from source to target to detector. The wave beam may be acoustic, optical, infrared or radar. Ranging systems can be used to measure proximity of objects to the air bag. The beams are usually narrow, less than 10 degrees and intercept a limited portion of the target.

Imaging Systems: These systems provide two-dimensional maps of some reflective feature of the vehicle interior. They may be visible optical or infrared. The two-dimensional images must be interpreted by a computer. An array of light and dark cells within the image must be correlated with hazardous and nonhazardous air bag deployment conditions.

The most advanced systems combine more than one type of sensing system in an attempt to provide reliable occupant detection for a wide variety of occupant types in a wide variety of real world conditions continuously updating dynamically (very close to real time).

6. Safety Belt Use Sensors

The driver side already has a restraint-use sensor to activate the warning light and buzzer if the driver is not using the safety belt. While some vehicles have a passenger side restraint use sensor, they are not required. Some manufacturers are installing more reliable safety belt use sensors, moving from a mechanical to a non-mechanical system (known as the Hall effect).

7. Seat Position Sensor

Seat position sensors can provide an indication of the position of the driver or passenger. If the seat is pulled all the way forward, the occupant is positioned close to the air bag. They offer a surrogate for a more direct measurement of driver size (the driver seat pulled all the way forward likely indicates a small person). They are available and Ford has already installed them MY 2000 Taurus.

C. High Speed Test Technologies

1. Dual Stage or Multiple Level Inflator

The benefit of a dual stage or multiple level inflator may overlap in both the low risk deployment option and in the high speed tests. Dual stage or multiple level inflators contain two separate initiators and require a control module which can sequence the firing of the stages under the defined conditions. In other words, each stage can be ignited separately, just stage A or just stage B, both stages can be fired together (A and B simultaneously), or stage A can be fired and then stage B can be fired after a time delay. Whether one or two stages fire would be determined by sensor input and algorithms. Sensor input can take many forms; for example: the severity of the crash, the position of the occupant, the size or weight of the occupant, the belt use of the occupant, the seat position of the occupant, etc.

The addition of satellite crash severity sensors (described above) may be necessary to help with the estimation of crash severity for the multi-stage inflator, or may be added for the proposed offset test.

2. Seat Belt Improvements

A high speed test, like the 35 mph belted test, could cause some manufacturers to improve their seat belts. Pretensioners and load limiters are the two likely candidates to help manufacturers meet the 35 mph belted test. Pretensioners take slack out of the belt system. Load limiters keep the belt from putting too much load on the chest of the occupant. This technology lets the occupant get to the air bag before allowing loads to build up on the seat belt that could cause chest injuries.

D. Analysis of Alternative High Speed Tests

Target Populations Related to High Speed Test Procedures

In Chapter II, the overall target populations for fatalities and injuries and for out-of-position occupants were estimated. In this section, we will relate the alternative high speed tests considered to target populations.

The objectives of the FMVSS 208 high speed test procedures are to provide crash simulations that are representative of real world crashes that have the potential for serious injury or fatality, and to test how well the vehicle and its restraint system protect outboard front seat occupants in those situations. One of NHTSA's objectives in this rulemaking is to determine what are the appropriate combination of tests to assure that air bags are designed to provide protection in the largest number of crashes causing serious injuries and fatalities, and at the same time to assure that unintended consequences (injuries caused by air bag deployment) are limited.

There were three types of high speed tests that were considered by the agency for this Final Rule:

1) Direct frontal barrier (like the current 30 mph rigid barrier test)

2) Oblique tests (like the current 30 degree angled, 30 mph rigid barrier test)

3) Offset tests (like the proposed Transport Canada 25 mph 40% offset deformable barrier test, the European offset deformable test and the unbelted offset test proposed by IIHS).

Major factors considered for these tests are:

1) The size of dummy to use in the test (5^{th} female, 50^{th} male, or both)

2) Whether the dummy is belted, unbelted, or both

3) The highest speed of the test and the range of speeds for the test (e.g., up to 30 mph, 20 to 30 mph)

4) Whether to run the oblique or offset tests on the left side (driver side) only or on both the left and right sides of the vehicle.

The types of crashes that could be covered by testing include:

1) a short duration, high deceleration crash pulse as is found in large numbers of potentially fatal crashes (represented best by a direct frontal barrier test),

2) a crash which forces manufacturers to design air bags that are wide enough to provide protection in angled impacts (represented best by an oblique test and to some extent by an offset impact),

3) cover special circumstances like the (25 mph offset crash) that results in some air bag designs deploying very late in the crash sequence, which cause occupants to be out-of-position when the air bag deploys, and

4) provide an incentive to limit aggressivity to a second vehicle to the extent possible.

Alternative tests considered by the agency for the high speed tests for the final rule are:

1) A belted full frontal rigid barrier impact for 5th female and 50th male dummies, either at 30 mph or 35 mph.

2) Oblique belted tests (left and right side up to 30 degrees) at 30 mph or 35 mph

3) An unbelted full frontal rigid barrier impact for 5th female and 50th male dummies, either at 25 mph or 30 mph.

4) Oblique unbelted tests (left and right side up to 30 degrees) at 25 mph or 30 mph

5) Belted 40% offset test (left side) at 25 mph

In the NPRM, a NHTSA research paper examined eight particular alternative FMVSS 208 test procedures. For a discussion of these test procedures the reader is referred to a NHTSA research paper placed in the docket entitled "Review of Potential Test Procedures for FMVSS 208, June 1998".[1] Based on comments to the docket and another year of crash data, this paper was updated and placed in the docket and is entitled "Updated Review of Potential Test Procedures for FMVSS 208, September 1999 ". The agency examined the number of drivers and magnitude of the injury population influenced by each test simulation, crash pulse stiffness, intrusion produced by the test procedure and test procedure lead time. Table V-1 presents a summary of that information.

[1]Review of Potential Test Procedures for FMVSS No. 208, June 1998: Hollowell, W.T, Gabler, C., Summers, S., and Hackney, J. See Docket No. NHTSA-1998-4405-10.

For this table only drivers were considered, right front passengers were not included since there is not a large difference between the driver and passenger in crash types. The target populations and AIS 3+ injuries were projected from NASS data of vehicles with air bags. All target populations in Table V-1 were limited to delta V's of 30 mph (48 kmph). However, the agency is considering some tests at 25 mph, some at 30 mph and other tests at 35 mph. Thus, the target populations are lower at 25 mph and higher at 35 mph. The effect of the different speeds considered on target populations is provided in Table V-2.

NHTSA determined that crash simulations involving an offset moving deformable barrier (MDB) represent the largest number of drivers and serious injuries, do a good job of representing real world crashes and would probably have a positive effect for compatibility. The vehicle-to-MDB tests have the desired stiff crash pulse, with considerable intrusion properties. Unfortunately, the agency believes the vehicle-to-MDB test procedure is a longer term (2-3 years) research and development activity beyond the time frame of the subject advanced air bag rule.

Table V-1
Alternative FMVSS 208 High Speed Crash Simulations Considered

	Test Procedure	Exposed Driver Population*	MAIS-3+ Driver Population	Crash Pulse/ Intrusion	Lead Time
1.	Rigid Wall/Full Frontal	263,981	5,054	stiff / low (0 - 6")	Available Now
2.	Rigid Wall Full Frontal Oblique	378,670 (L+R)	8,875 (L+R)	soft /high (> 6")	Available Now
3.	Offset Deformable Barrier	378,670 (L+R)	8,875 (L+R)	soft /high (> 6")	Available Now
4.	Vehicle-MDB Full Frontal	263,981	5,054	stiff /low (0 -6")	2-3 years
5.	Vehicle-MDB Offset Stiff	932,907 (L+R)	20,297 (L+R)	stiff /high (> 6")	2-3 years
6.	Vehicle-MDB Offset Soft	378,670 (L+R)	8,875 (L+R)	stiff /high (> 6")	2-3 years

* Drivers in crashes annually at < 30 mph delta V, estimated from NASS-CDS.

The full frontal rigid barrier test (#1) has a stiff crash pulse promoting the design of frontal structures that manage crash energy and improved occupant restraints. It is believed this procedure has a positive influence on vehicle compatibility. This procedure has a large MAIS-3+ driver target population, but has little, if any, intrusion affects. The oblique rigid wall frontal test (Test #2), currently a part of 208 and the offset test (Test #3) are considered to have soft crash pulses. Preliminary data reviewed by NHTSA indicates good performing vehicles in the offset can have less aggressive vehicle characteristics.

Test #2 (oblique test) and Test #3 (offset test) have slightly larger driver MAIS-3+ target populations than Test #1. With the combination of full frontal and oblique or offset requirements, it is believed that to do well in both tests, a vehicle's structure must not be too stiff (e.g., that the occupant cage must be well designed and the vehicle frontal structure must be optimized for energy dissipation). The agency does not believe this combination of crash tests will adversely influence vehicle-to-vehicle compatibility.

Table V-2
Annual Driver Injury Estimates

	AIS 3+ Injuries*	**Fatalities***
25 mph Frontal Unbelted	2,408	1,121
25 mph Oblique Unbelted	4,733	2,408
30 mph Frontal Unbelted	3,032	1,798
30 mph Oblique Unbelted	5,325	3,197
25 mph Offset Belted	3,156	1,140
30 mph Frontal Belted	2,022	852
30 mph Oblique Belted	3,550	1,514
35 mph Frontal Belted	2,118	1,125
35 mph Oblique Belted	3,720	2,000

* Target population estimates for drivers injured or killed at < listed delta V and crash type.

Because of the large number of tests to be considered, the agency rated the various tests according to a variety of factors and then considered combinations of tests to identify a set of tests which would promote the most effective air bag performance in the real world with the fewest number of tests. The following tables provide the agency's assessment of the various tests. The first three columns rate the tests by type; does the test have a soft or stiff crash pulse, will it result in more or less than 6 inches of intrusion for current vehicles, and is it a head-on or angled test. Next the agency rated on a scale of 0 to 5 whether the test would force manufacturers to make improvements in their vehicles.

0 - no effect on design for this factor

1 - small effect on design

3 - possible effect

5 - likely effect

For bag volume and depth the ratings are:

1 - small air bag

3 - medium size air bag

5 - large air bag

The factors considered included whether the test had an effect on crash sensing, multi-stage inflation, air bag volume depth and width and occupant sensing. These were all considered mutually exclusive for each test, with the exception that occupant sensing and multi-stage inflation are often times linked together.

The tests that drive likely improvements are the 25 mph (40%) belted offset test, which will promote improvements in crash sensing and timing of the air bag. The 5^{th} female in the 30 mph unbelted frontal barrier test would promote designs toward improved occupant sensing and multi-stage inflation. The unbelted oblique test would promote wider air bags. Finally, the unbelted 50^{th} percentile male 30 mph unbelted frontal barrier crash test requires the deepest air bags.

One of the decisions the agency made between the SNPRM and the final rule was to reduce the number of tests by two, by not testing the 5^{th} female dummy in the unbelted oblique +/- 30 degree tests. The agency believes that the 50^{th} male dummy unbelted is a much more severe test of effectiveness of the width of the air bag and oblique tests with the belted 50^{th} or belted and unbelted 5^{th} female dummy are unnecessary.

There are possibly trade-offs in design between meeting the at-risk out-of-position tests and at the same time meeting the high speed tests. Manufacturers could design their vehicles to the minimal performance required in the high speed test in an attempt to get the least aggressive air bag in the out-of-position tests. The agency believes it is possible to have separate design paths for the high speed and out-of-position tests. The target populations are much greater for the high speed tests than for the out-of-position tests. Thus, overall the greatest potential target population and the greatest potential benefit would be to require the strictest test regime for the high speed tests. This would require a high level of performance for air bags in the high speed tests and, at the same time, require the out-of-position test to be passed.

Table V-3
BELTED TESTS

	Crash Pulse		Intrusion		Occupant Kinematics		Driver Target Population		Improved Crash Sensing	Requires Multi-Stage Inflation	Bag Volume Depth	Bag Volume Width	Required Occupant Sensing
	Soft	Stiff	<6"	>6"	Head-on	Angle	AIS 3+	Fatals					
30 mph Frontal Barrier		X	X		X		2,022	852					
50th									1	0	1	1	0
5th and 50th									1	0	1	1	0
35 mph Frontal Barrier		X	X		X		2,118	1,125					
50th									1	0	1	1	0
5th and 50th									1	0	1	1	0
30 mph Oblique (+/- 30 deg)	X			X		X	3,550	1,514					
50th									1	0	1	1	0
5th and 50th									1	0	1	1	0
25 mph Offset (40%)	X		X		X		3,156	1,140					
5th									5	0	1	1	0

Table V-4
UNBELTED TESTS

	Crash Pulse		Intrusion		Occupant Kinematics		Driver Target Population		Improved Crash Sensing	Improved Structural Integrity	Requires Multi-Stage Inflation	Bag Volume Depth	Bag Volume Width	Required Occupant Sensing
	Soft	Stiff	<6"	>6"	Head	Angle	AIS 3+	Fatals						
25 mph Frontal Barrier		X	X		X		2,408	1,121						
50th									1	1	0	2	1	0
5th and 50th									1	1	0	2	1	0
25 mph Oblique (+/- 30 degree)	X		X			X	4,733	2,408						
50th									1	1	0	1	5	0
5th and 50th									1	1	2	1	5	2
30 mph Frontal Barrier		X	X		X		3,032	1,798						
50th									1	1	0	5	1	0
5th and 50th									1	1	5	5	1	5
30 mph Oblique (+/- 30 degree)	X			X		X	5,325	3,197						
50th									1	2	0	1	5	0
5th and 50th									1	2	3	1	5	3

Table V-5
TEST COMBINATIONS

	Crash Pulse		Intrusion		Occupant Kinematics		Driver Target Populations		Improved Crash Sensing	Requires Multi-Stage Inflation	Bag Volume Depth	Bag Volume Width	Requires Occupant Sensing	# Of Tests
	Soft	Stiff	<6"	>6"	Head-on	Angle	AIS 3+	Fatals						
1 Up to 30 mph Frontal (B)		X	X		X		13,535	6,987	1	0	1	1	0	7
20-30 mph Frontal (U)		X	X		X				1	5	5	1	5	
5^{th} and 50^{th} all above														
20-30 mph unbelted 50th +/- 30	X			X		X			1	3	1	5	3	
Degree Oblique														
Up-25 mph Offset (B) 5^{th} L	X		X		X				5	0	1	1	0	
											Total Score #1 = 25			
2 Up to 30 mph Frontal (B)		X	X		X		12,319	5,521	1	0	1	1	0	7
20-25 mph Frontal (U)		X	X		X				1	0	2	1	0	
5^{th} and 50^{th} all above														
20-25 mph unbelted 50^{th} +/- 30	X			X		X			1	3	1	5	3	
Degree Oblique														
Up-25 mph Offset (B) 5^{th} L	X		X		X				5	0	1	1	0	
											Total Score #2 = 18			
3 Up to 35 mph Frontal (B)		X	X		X		13,631	7,260	1	0	1	1	0	7
20-30 mph Frontal (U)		X	X		X				1	5	5	1	5	
5^{th} and 50^{th} all above														
20-30 mph unbelted 50th +/- 30	X			X		X			1	3	1	5	3	
Degree Oblique														
Up-25 mph Offset (B) 5^{th} L	X		X		X				5	0	1	1	0	
											Total Score #3 = 25			
4 Up to 35 mph Frontal (B)		X	X		X		12,415	5,794	1	0	1	1	0	7
20-25 mph Frontal (U)		X	X		X				1	0	2	1	0	
5^{th} and 50^{th} all above														
20-25 mph unbelted 50^{th} +/- 30	X			X		X			1	3	1	5	3	
Degree Oblique														
Up-25 mph Offset (B) 5^{th} L	X		X		X				5	0	1	1	0	
											Total Score #4 = 18			

VI. POTENTIAL BENEFITS

This chapter estimates the potential benefits of advanced air bags. These benefits would be achieved from the required tests and new injury criteria using the pre-MY 1998 air bag systems as the base. The benefit calculations are based on limited available laboratory crash tests and real-world crash data. Most of the real-world crash data involved baseline vehicles that had passed the unbelted 30 mph rigid barrier tests for the 50th percentile male dummy. The benefit assessment methodology assumes that manufacturers would make as few changes as possible to meet the required tests. The process and theory is presented in the methodology section. However, two assumptions are examined for air bags designed to meet the 25 mph rigid barrier tests. One assumes that air bag power would be maintained at current levels. The other assumes that manufacturers would design their air bags to maximize air bag performance in the 25 mph rigid barrier tests, rather than in the 30 mph rigid barrier tests. Different approaches were examined to estimate the impacts of air bags designed to meet the 25 mph rigid barrier tests on injuries and fatalities under the second assumption. These estimates for 25 mph rigid barrier tests are presented in the subsections titled "impact of 25 mph rigid barrier unbelted tests". In addition to the benefits assessment, this chapter also provides sensitivity studies to address the impacts of an increased belt use rate and MY 1998 redesigned air bags on the benefits of advanced air bags.

The analysis includes several alternative tests and new injury values to require manufacturers to provide advanced air bag systems that protect various sizes of occupants in a variety of frontal crash scenarios, e.g., different occupant positions, crash severities, crash pulses, and angles. The alternative tests along with the new injury criteria are classified by their general objectives: (1) minimizing the risk of air bag induced fatalities and serious injuries, and (2) improving general occupant protection. Table VI-1 shows conceptually the alternative tests and their applicable target groups.

Table VI-1
Crash Tests by Impact Group

Type of Test	Minimize Risks of Air Bag Induced Fatalities & Injuries			Preserve and Improve Occupant Protection From High Speed Crash Tests			
	At-Risk Groups			Front-Outboard Occupants			
				Improved Crash Testing		Improved Sensor Algorithm	
	Infants	Children (1-12 Years Old)	Adults in Close Proximity	50th Percentile Male[1]	5th Percentile Female	in Full Frontal[2] Crashes	in Offset Crashes
Suppression When Present	x	x[3]					
Suppression When Out-Of-Position	x	x	x				
Low Risk Deployment	x	x	x				
Up to 30 mph Belted, or Up to 35 mph Belted Rigid Barrier, 0 Degree With 50th Percentile Male				x			
Up to 30 mph Belted Rigid Barrier, 0 Degree With 5th Percentile Female					x		
Up to 25 mph Offset With Belted 5th Percentile Female Driver			x			x	x
20 to 25 mph Unbelted, or 20 to 30 mph Unbelted 0 and ± 30 Degree With 50th Percentile Male			x	x			
20 to 25 mph Unbelted, or 20 to 30 mph Unbelted With 5th Percentile Female			x		x		

1. Population includes those that can be represented by 95th percentile male dummy.
2. Full frontal crashes are defined as those with impact force from the 12 o'clock direction.
3. Because the 6 year old dummy (which weighs about 54 pounds with instrumentation) is the largest used, the test is assumed to protect children only up to 54 pounds.

This analysis estimates the benefits for these two categories separately. Each category includes two parts: (1) benefits from fatality reduction, and (2) benefits from nonfatal MAIS 2-5 injury mitigation. The general procedure is first to identify the baseline target population and then to estimate the fatal or injury reduction rate/percentage for each test using the pre-MY 1998 injury probability as the base. Crash test results from Chapter IV are used to calculate injury probabilities. The injury reduction rate is applied to the corresponding target population which results in injury reduction benefits.

The benefits of minimizing air bag risks are discussed for three at-risk groups in three parallel sections: RFCSS (infants in rear facing child safety seats), children (1-12 years old), and close-proximity adults. The benefits for improved protection from high speed crash tests are analyzed by injured body regions. The perpendicular (0 degree) and oblique ($\pm$ 30 degrees) rigid barrier tests on restrained and unrestrained 50th percentile males and/or 5th percentile females with the Injury Criteria Performance Limits (ICPLs) would improve overall air bag effectiveness and thus apply to all front-outboard occupants. The offset tests are intended to improve sensors and algorithms for air bag deployment decisions so that the air bag would inflate in time to provide adequate protection to occupants who otherwise would not be protected by late-deploying air bags. The 25 mph offset belted test would impact out-of-position adult fatalities and injuries in full frontal, partial frontal, and offset crashes. Note that full frontal crashes are defined as those crashes with an impact force from the 12 o'clock direction. Partial frontal crashes are defined as those crashes with an impact force from 10, 11, 1, and 2 o'clock directions.

For each target population group, the analysis provides benefit estimates for the alternative tests and hypothetical air bag systems assumed to pass the tests. The benefit summary section provides benefits for air bag systems assuming to meet a combination of suppression, low-risk deployment, and either of the following alternatives from the high speed crash tests.

Alternative #1 of the high speed crashes includes: a) 20 to 25-mph rigid barrier, perpendicular test with unrestrained 5th percentile females, b) 20 to 25-mph rigid barrier, perpendicular and +/- 30 degrees tests with unrestrained 50th percentile males, c) 0 to 30-mph rigid barrier, perpendicular test with restrained 50th percentile males, d) 0 to 30-mph rigid barrier, perpendicular test with restrained 5th females, and e) 0 to 25-mph offset test with restrained 5th percentile females.

Alternative #2 includes: a) 20 to 30-mph rigid barrier, perpendicular test with unrestrained 5th percentile females, b) 20 to 30-mph rigid barrier, perpendicular and +/- 30 degrees test with unrestrained 50th percentile males, c) 0 to 30-mph rigid barrier, perpendicular test with restrained 50th percentile males, d) 0 to 30-mph rigid barrier, perpendicular test with restrained 5th percentile females, and e) 0 to 25-mph offset with restrained 5th percentile females.

Alternative #3 of the high speed crashes includes: a) 20 to 25-mph rigid barrier, perpendicular test with unrestrained 5th percentile females, b) 20 to 25-mph rigid barrier, perpendicular and +/- 30 degrees tests with unrestrained 50th percentile males, c) 0 to 35-mph rigid barrier, perpendicular test with restrained 50th percentile males, d) 0 to 30-mph rigid barrier, perpendicular test with restrained 5th females, and e) 0 to 25-mph offset test with restrained 5th percentile females.

The hypothetical systems discussed here are linked together with potential technologies. One is a suppression type system in which air bags would not be deployed under certain situations. For these suppression systems, dynamic suppression and static weight suppression systems will be discussed. The other type is an advanced system that incorporates a higher speed threshold for air bag deployment and a multi-stage inflation system based on crash severity and belt usage. This same system, combined with a 54-pound weight sensor for suppression, will also be examined. The 54-pound weight limit is chosen to correspond to the weight represented by the 6 year old child dummy. Note that the agency does not have a preference for any particular air bag system, but is setting up tests that would allow manufacturers to use alternatives like these to meet the ICPLs. Descriptions of these systems and the tests that each system would be required to pass are as follows:

Static Weight-Based Air Bag Suppression

This system is designed mainly to detect the presence of a child using weight as the threshold. Thus, it applies only to passenger side air bags. The passenger side air bags would not be deployed if the front passenger seat weight sensor measures a value below a certain pre-defined weight criterion. For example, the air bag would not be deployed if the passenger weighs 54 pounds or less for the 54-pound static weight suppression system. This type of system could meet the tests for infants in rear facing child safety seats and for 3 year old and 6 year old dummies. The 6 year old dummy, with instrumentation, weighs 53.6 pounds.

Out-Of-Position Air Bag Suppression

In this system the air bag will be automatically shut off when an occupant is too close to the air bag module. Proximity sensors, e.g., ultrasound and/or infrared, may be utilized to sense the position of the occupant. This system could meet a suppression test.

Multi-Stage Inflation Based on Crash Severity and Belt Use

Driver and passenger air bags would be inflated at different power levels based on each occupant's restraint system usage and crash severity. For purposes of this analysis, the multi-stage inflation system is defined to have the same operating characteristics as the dual power level system as stated in Table VI-2. These characteristics are analytical assumptions, not NHTSA preferences. If equipped with a weight sensor, the system has the same definition as that stated in Table VI-2. In addition, the air bag would not be fired if the passenger weighs less than or equal to the weight threshold. Note that nothing in the alternative tests require manufacturers to have multi-stage inflation capability or to have the same thresholds as in the example. The stage 1 low level deployment of this type of system is assumed, for analytical purposes, to meet the low risk deployment test for infants, children and adults in close proximity to the air bag. In addition, the second stage of the system is assumed, for analytical purposes, to meet one of the three high speed alternatives as described earlier.

Table VI-2
Benefit Analysis Assumptions for
Multi-Stage Inflation System Based on
Crash Severity and Restraint Use

Inflation Power	Belted (MPH)	Unbelted (MPH)
Suppression	< 18	< 14
Stage 1 Low Level Power	18-30	14-25
Stage 2 Full Power	> 30	> 25

The rest of the chapter is organized as follows: the first section (VI.A) establishes the baseline target fatal/injury population. The second section (VI.B) discusses the methodology for deriving the reduction in fatality and injury rate/percentage points. The third section (VI.C) estimates benefits first for minimizing air bag induced fatalities and serious (MAIS 3-5) injuries and then for improving occupant protection benefits (fatalities and MAIS 2-5 injuries) from high speed crash tests. Benefits for fatalities and MAIS 2-5 injuries are discussed separately for each relevant test, and pre-defined hypothetical air bag systems. The benefit summary section (VI.D) provides overall benefit tables for all the tests and systems. The sensitivity study section (VI.E) provides changes in benefits resulting from increased safety belt usage. Finally, the last section (VI.F) discusses occupant behavior and its potential effects on benefits.

A . Target Population

The pre-1998 baseline population is used to estimate benefits for three reasons: 1) manufacturers introduced the MY 1998 vehicles with redesigned air bags incrementally as opposed to equipping all MY 1998 vehicles with the redesigned air bags when they were introduced. 2) information on the extent and impact of 1998 models with redesigned air bags in the current fleet is inadequate to provide a basis for determining a full-fleet redesigned baseline estimate, and 3) the MY 1998 sled certified air bags may not be what manufacturers would have designed if they had more lead time. So, the current redesigned air bags, as found in MY 1998 vehicles, is probably not a steady, constant baseline.

For each at-risk group, the annualized fatal target population, as described in Chapter II, is projected from those actual fatal cases collected in NHTSA's Special Crash Investigation (SCI) Program as of January 1, 2000 to a projected level assuming all passenger cars and light trucks were equipped with air bags. Each at-risk MAIS 3-5 injury level was adjusted from at-risk fatalities by multiplying a corresponding factor. The factor is the ratio of MAIS 3-5 injuries to fatalities with air bags recorded as the injury source in the 1993-1998 CDS. Note that at-risk injuries do not include MAIS 2 injuries because MAIS 2 injuries are commonly cited in the crashes. It would overestimate adverse air bag effects if MAIS 2 injuries were estimated and included in the target population.

Improved occupant protection target fatalities and MAIS 2-5 injury populations from high speed crash tests are derived from the 1993-1997 CDS. Pre-MY 1998 air bags were proven to be 10 percent (not statistically significant) effective in reducing MAIS 2-5 injuries. With new tests and injury criteria, the advanced air bags would reduce these injuries further. Therefore, MAIS 2 injuries were included in the target population for the high speed tests. Similarly, the annualized front-outboard occupant fatalities from CDS then are adjusted to the 1997 FARS level to overcome the underreporting problem in CDS for fatalities. The annualized target MAIS 2-5 injury population is adjusted to the 1997 GES CDS-equivalent level to get a better national estimate. This target population is further divided into two subgroups:

1. **Adult front-outboard occupants affected by improved crash testing and injury criteria.**

Fatalities. The 15,447 adult (excluding 278 child fatalities) front-outboard occupant fatalities in frontal crashes were derived from Table II-3 (15,725 - 278 = 15,447). The 278 child (age 0-12 years old) fatalities were derived by adjusting the annualized child fatalities from 1993-1997 CDS to the 1997 FARS level. These data were derived from 1997 data, which means that incremental benefits will be compared to a fleet of vehicles equipped with pre-MY 1998 air bags. Of these 15,447, 12,116 (78 percent) occupants with heights of at least 65 inches are assumed to be represented by the 50th percentile male dummy, and the remaining 3,331 are assumed to be represented by the 5th percentile female dummy.

MAIS 2-5 Injuries. The 258,287 adult (excluding 3,348 child MAIS 2-5 injuries) front-outboard occupant MAIS 2-5 injuries in all frontal crashes were derived from Table II-12 (258,287 = 261,635 - 3,348). Of these 258,287, 201,541 (78 percent) occupants are assumed to be represented by the 50th percentile male dummy, and the remaining 56,746 are assumed to be represented by the 5th percentile female dummy. The 3,348 child (age 0-12 years old) MAIS 2-5 injuries were derived by adjusting annualized child fatalities from 1993-1997 CDS to the 1997 GES CDS-equivalent level.

2. **Front-outboard improperly positioned occupants affected by improved sensor capability**. Improperly positioned occupants are defined as those that the air bag did not help as much as it could have if they were properly positioned. These are people that were not killed or injured by the air bag, but potentially could have been saved or their injury levels could have been mitigated to a lesser severity level if the air bag characteristics were in some way improved (e.g., quicker deployment times). There are several factors that may cause an occupant to be improperly positioned, including sitting too close to the air bag, moving toward the air bag while braking, and late air bag deployment. The analysis considers that improperly positioned occupants are part of a target population that would benefit from improved sensors. The probability that an occupant would be improperly positioned is different in full frontal and offset crashes. Nusholtz[1] concluded that about 19 percent of total occupants associated with offset crashes and 1 percent of total occupants associated with full frontal crashes would be out-of-position. However, the paper didn't indicate how different the size of the "out-of-position" population was between fatalities and MAIS 2-5 injuries. To investigate the relationship between fatalities and injuries, data from the 1993-1997 CDS were analyzed. They showed that about 28 percent of unbelted fatalities and 36 percent of unbelted MAIS 2-5 injuries were in vehicles where drivers had made a brake maneuver to avoid a frontal crash. If these occupants were considered to be improperly positioned, the 28 percent unbelted fatalities accounted for 19 percent of all fatalities in frontal crashes. The improperly positioned MAIS 2-5 proportion was slightly less, about 14 percent of all MAIS 2-5 injuries. Because percentages are close and the Nusholtz 19 percent estimate was based on a more rigorous analysis, improperly positioned occupants are

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[1] Nusholtz, G., Xu, Lan, & Kostyniuk, G., "Estimation of Occupant Position from Probability Manifolds of Air Bag Fire-Times", SAE # 980643, Air Bag Technology, SP-1333, SAE, 1998.

assumed, for both fatalities and MAIS 2-5 injuries, to account for 19 percent of total occupants associated with offset crashes and 1 percent of total occupants associated with full frontal crashes. Based on Stucki's[2] paper, offset crashes represent 77.9 percent of all frontal crashes.

Fatalities. Thus, there are 2,320 (34 in full frontal: 15,447*0.221*0.01; 2,286 in offset: 15,447*0.779*0.19) projected improperly positioned adult fatalities. Of these 2,320, 1,839 (27 in full frontal; 1,812 in offset) are drivers and 481 (7 in full frontal; 474 in offset) are passengers.

MAIS 2-5 Injuries. There are 38,796 (569 in full frontal: 258,286*0.221*0.01; 38,227 in offset: 258,286*0.779*0.19) projected improperly positioned adult MAIS 2-5 injuries. Of these 38,796, 30,565 (448 in full frontal; 30,117 in offset) are drivers and 8,231 (121 in full frontal; 8,110 in offset) are passengers.

Table VI-3 summarizes the estimated baseline target population assuming all vehicles in the fleet were equipped with air bags.

[2] Stucki, Lee, "Analysis of Crash Data on Drivers With Air Bags in Frontal Crashes to Support a Frontal Offset Test Procedure", 1988-1996 National Analysis Sampling System (NASS), September 3, 1997

Table VI-3
Target Population
Annual Estimates Assuming a Full Air Bag Fleet

	Minimize Risks of Air Bag Induced Fatalities & Injuries			Improve Occupant Protection From High Speed Crash Tests			
	At-Risk Groups			Front-Outboard Occupant Fatalities/Injuries			
				Improved Crash Testing		Improved Sensor Algorithm	
	Infants	Children (1-12 Years Old)	Adults in Close Proximity	50th Percentile Male	5th Percentile Female	In Full Frontal Crashes	In Offset Crashes
Fatalities							
Total (Drivers) (Passengers)	18 (18)	105 (105)	64 (46) (18)	12,116 (10,160) (1,956)	3,331 (2,081) (1,250)	34 (27) (7)	2,286 (1,812) (474)
MAIS 2-5 Injuries							
Total (Drivers) (Passengers)	9 (9)	200 (200)	53 (38) (15)	201,541 (164,827) (36,714)	56,746 (38,664) (18,082)	569 (448) (121)	38,227 (30,117) (8,110)

Source: NHTSA Special Crash Investigation (SCI) cases as of January 1, 2000, 1997 FARS, 1993-1997 CDS, and 1997 GES
Note: Fatalities derived from 1993-1997 CDS are adjusted to 1997 FARS level; Injuries are adjusted to 1997 GES CDS-equivalent level; At-risk injuries included only MAIS 3-5 injuries.

B. Overview of Method

The basic benefit estimation procedure consists of four steps: (1) establish the fatality and MAIS 2-5 injury probability (p) for each individual injury criterion (i.e., HIC, chest g's, chest deflection, Nij, etc.); (2) calculate the reduction rate/percentage (r); (3) calculate the weighted reduction rate/percentage; and (4) derive benefits. The following is a detailed description of each step.

Step 1: Establish the fatality and MAIS 2-5 injury probability (p). This step derives fatal/injury probabilities (p) for each vehicle test data included in the analysis by injury criterion (i.e., HIC, chest g's, chest deflection, Nij, etc.). The best predictor of fatal injury for chest and neck (Nij) is the AIS-5+ curve. The overwhelming majority of AIS-5 and AIS-6 injuries to the chest and neck result in a fatality. Thus, the AIS-5+ curve is a good proxy measure for fatality. Chapter III provides the algorithms for these curves, based on biomechanical data. Thus, the analysis uses AIS-5+injury curve to derive the fatality probability for Nij and CTI. The probability of a fatality, for example, for a HIC 700 is 1.7 percent (lognormal curve, see Table III-5), and for Nij=1.0 is 6.8 percent (see Figure III-5). And the corresponding MAIS 3-5 injury probability at HIC 700 for head and Nij=1 for neck is 29.5 and 23.0 percent, respectively.

Step 2: Calculate the reduction rate/percentage (r). The process is different for tests that minimize air bag risks and for those that improve air bag benefits. <u>For tests that minimize risk of air bag induced fatalities</u>, for each injury criterion, the average fatality/injury probability of the test results (p_b) is first measured against that (p_a) of the same tests after setting those tests that failed to the standard ICPLs. The reduction percentage (r) is 1 minus the ratio of p_a to p_b. That is, for each injury criterion,

$$r = 1 - p_a/p_b.$$

p_b = average fatality/injury probability of crash test results

p_a = average fatality/injury probability of crash test results after setting those with failed values to the ICPL.

For example, low risk deployment reduction rates for infants were based on HIC values of four 213 tests with a 12 months old CRABI in a child safety seat. The average fatal probability (p_b) of the test results for head injury was 24.35 percent based on the lognormal curve. Three of these vehicles failed the HIC 390 ICPL and those HIC values are then set to be 390 (the head ICPL). The value p_a (0.018 percent) is the average fatal probability of this new set of four values (one value didn't change because it already passed the HIC 390). Therefore, the low risk deployment reduction rate for infants is 99.93=(1 - 0.0018/0.2435). The formula is derived based on the assumption that there is a 100 percent chance of being killed or seriously injured by pre-98 model air bags for at-risk groups and current test results corresponding to that 100 percent.

<u>For tests that improve occupant protection</u>, for each injury criterion, the actual percentage reduction (r) in the fatality and injury probabilities for each vehicle tested are calculated. Benefits are realized from improved injury criteria and the various crash test requirements (e.g., 30 mph rigid barrier with 5th percentile female and the 25 mph belted offset test which improves the sensor algorithm). The analysis examines FMVSS 208 tests with unrestrained 50th percentile males, and Transport Canada tests (25 mph offset and 30 mph rigid barrier frontal barrier with restrained 5th percentile females) that failed the proposal injury values. It estimates the fatal/injury reduction percentage for each of these tests if they just meet the proposal injury values. For example, a vehicle in the 30 mph rigid barrier test with a restrained 5th percentile female driver dummy has an Nij=1.2. Then the reduction in the percentage of fatal neck injuries for this vehicle would be 1.7 percent, which is the difference between the fatality probability at Nij=1.2 (8.5 percent) and the fatality probability at Nij=1.0 (6.8 percent; these Nij values are put into the formula for AIS-5+ injuries shown in Figure III-5).

Step 3: Derive the weighted reduction percentage. The weighted reduction percentage is calculated using the following formula:

$$r = \Sigma w_i * r_i, \quad i \in \{1,2,3,...k\}$$

Where r = total percent reduction in fatality/injury probability

w_i = the weights

r_i = the reduction in fatality/injury probability

k = the total reduction percentage calculated.

Again the process and the assumptions made are different for tests that minimize air bag risks than for those that improve air bag benefits. For tests that minimize risk of air bag induced fatalities, w_i is the proportion of various injured body regions in the at-risk population and r_i ($=1 - p_a/p_b$) is the corresponding reduction percentage. For example, the reduction rate for air bags passing the low risk deployment for children 1 to 12 years old were based on the out-of-position data on a 6 years old dummy. About 29 percent (w_1) of at-risk children 1-12 years old suffered a fatal head injury, and 71 percent (w_2) of these children had a fatal neck injury. So, k=2 (the number of injury criteria assessed) and the combined fatal r is 0.9034 (=0.29*0.9319 + 0.71*0.8917) percent if based on the lognormal injury curve. The numbers 0.9319 and 0.8917 are the reduction percentages for fatal head and neck injuries as described in step 2 previously.

Note that the driver at-risk population can't separate the head and neck injuries, thus it is inappropriate to use the individual head and neck reduction rate. In this case, the fatality/injury probabilities p_a and p_b in the reduction rate formula as in step 2 represent the combined fatal/injury probabilities of head and neck. The combined fatal/injury probability are calculated by assuming that the probabilities for each body region are independent of each other and benefits for different body regions. The calculation can be determined with the following formula:

$$p_a \text{ (or } p_b) = p_1 + p_2 - p_1 * p_2$$

where p = the combined probability of p_1 (head probability) and p_2 (neck probability).

For p_b, p_1 and p_2 are the average fatality/injury probabilities of head and neck derived from the test results. While for p_a, p_1 and p_2 are the average fatality/injury probabilities of head and neck derived from the same set of tests after setting those that with failed values to ICPLs. The same procedures are applied to calculate the combined probability of an adult having a MAIS 2-5 injury.

For tests that improve occupant protection, the total reduction percentage for each injury criterion (head, chest, and neck) is derived from the sales weighted cumulative percentage of all of the vehicles tested. The percentage point reduction for each vehicle tested is applicable only to the proportion that each vehicle represents within the tests. In other words, by assuming that proportion for each vehicle tested is the vehicle's proportion of on-road exposure, the reduction percentage is weighted by the vehicle's sales volume. The sum of these reduction percentages is the total reduction percentage in fatality/injury probability. The notations of the total reduction equation have a different interpretation:

$$r = \sum w_i * r_i, \quad i \in \{1,2,3,\ldots k\}$$

Where r = total percent reduction in fatality/injury probability

w_i = the proportion of the vehicle's sales to the sales of all the vehicles tested

r_i = the reduction in fatality/injury probability from the tested level to the ICPL level for each vehicle

k = the number of vehicles failing to meet the specific injury ICPL

Note that some vehicle tests had a 0.0 percent fatal/injury reduction since they already comply with the ICPLs. Because this process examines each individual injury criterion at different levels, it cannot use the combined probability concept. Head, neck, and chest fatal and MAIS 2-5 injuries are assessed separately, and percentage reductions are applied to head, neck, and chest fatalities/injuries, respectively. The total reduction benefit is the sum of head, neck, and chest reduction benefits.

Step 4: Derive benefits. The last step is to apply the reduction rate/percentage to the corresponding population to estimate benefits:

$$B = TP * r$$

where B = benefits (lives that would be saved or MAIS 2-5 injuries that would be mitigated)

TP = target population of the corresponding test

r = total reduction rate or reduction percentage

The following are additional adjustments that are used to calculate safety impacts:

1. All the infants killed or seriously injured by air bags suffered head injuries, therefore, only the HIC measurement is used for infants.

2. Also based on the SCI cases, all non-infant children suffered fatal or serious neck or head injuries. A combined fatality/injury reduction percentage of head (HIC) and neck injury is calculated for children.

3. The CTI, a combination of chest g's and chest deflection, injury probability curve is used to estimate the risk of chest injury. For each test type, the CTI value of those vehicles that failed to meet the standard (i.e., chest g and chest deflection) would measure against the CTI at the ICPLs. For example, if a vehicle tested with a 50^{th} male dummy had a CTI=1.17[3] at chest g 66 g's (failed) and 45 mm chest deflection, the CTI would measure against CTI=1.10 at chest g 60 g's (proposed ICPL) and 45 mm chest deflection. Note that CTI is being used for chest benefit analysis but is not an injury criterion in the final rule.

4. Tests on model year 1998 or 1999 vehicles were used only if there were no tests on pre-MY1998 models.

Table VI-4-A lists the fatality reduction rates for the target population for the alternatives to minimize air bag induced fatalities. Reduction rate estimates shown are based on the Expanded

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[3] CTI = chest g/90 + chest deflection/103 for the 50^{th} male dummy.

Prasad/Mertz HIC curve, while those based on the lognormal curve are in parentheses. Table VI-4-B lists the injury reduction rates for the at-risk MAIS 3-5 injuries. The estimated reduction rates from low risk deployment for infants were based on the 213 crash tests on 12-month old CRABI with a deployed air bag; for children (1 and 12 years old), rates were based on the out-of-position tests with a six years old dummy right on the air bag module; for drivers, rates were based on out-of-position tests with 5th percentile females. There are no out-of-position test data for adult passengers and thus their reduction rates were adapted from children. The estimated reduction rates from 25 mph offset with a 5th percentile female were based on the Transport Canada (TC) crash test data.

Table VI-4-A
Fatality Reduction Rates For At-Risk Groups

Type of Tests	Minimize Risks of Air Bag Induced Fatalities			
	Infants	Children (1-12 Years Old)	Adults Passengers in Close Proximity	Drivers in Close Proximity
Low Risk Deployment	99.93% (92.19%)[1]	90.34% (91.22%)	90.34%[2] (91.22%)	52.23% (52.23%)
Up to 25 mph Offset, Belted 5th Female			13.26% (13.26%)	38.37% (38.37%)

1. Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.
2. Percentages are assumed to be identical to the estimates for children.

Table VI-4-B
MAIS 3-5 Reduction Rates For At-Risk Groups

Type of Tests	Minimize Risks of Air Bag Induced MAIS 3-5			
	Infants	Children (1-12 Years Old)	Adults Passengers in Close Proximity	Drivers in Close Proximity
Low Risk Deployment	60.15% (55.78%)[1]	76.83% (77.10%)	76.83%[2] (77.10%)	51.90% (51.90%)
Up to 25 mph Offset, Belted 5th Female			18.83% (18.83%)	47.82% (47.82%)

1. Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.
2. Percentages are assumed to be identical to the estimates for children.

Tables VI-5-A and VI-5-B show the weighted percentage point reduction of fatal and MAIS 2-5 injury probabilities for the improved air bag protection from high speed crash tests. Reduction rate estimates shown are based on the Expanded Prasad/Mertz HIC curve, while those based on the lognormal curve are in parentheses. Based on the previous discussion for the additional CTI adjustment (#3), chest reduction percentages are derived by calculating the weighted reduction in fatality/injury probability from the tested CTI level to the CTI at the standard level. Note that no Nij values were collected for 30 mph unbelted tests with 50th percentile male dummies on pre-MY 1998 vehicle models. Based on Transport Canada 30 mph rigid barrier belted tests on 50th percentile male dummies, the test results are not very different between pre-MY 1998 and MY 1998 vehicle models. Therefore, the MY 1998 tests results are used as a baseline to calculate neck reduction percentages for this test. Also note that the agency had three 30 mph rigid barrier 30 degree oblique tests with unrestrained 50th percentile males (two on right angular and one on left angular). These tests passed the ICPLs, therefore, there was no additional reduction in fatalities or injuries from vehicles that already passed the 30 mph rigid barrier perpendicular tests with 50th percentile males. The estimated reduction rates for the 30 mph, rigid barrier unrestrained tests with 5th percentile population were based on these tests and those failed the 25 mph restrained with 5th percentile females.

Table VI-5-A
Percentage Point Reduction of Fatal Probability for
Improved Occupant Protection From High Speed Crash Tests

Type of Tests		Front-Outboard Occupant Fatalities		
		Head	Neck(Nij)	Chest
20 to 30 mph Rigid Barrier, 0 and ± 30 Degree Unbelted 50th Percentile Male	Drivers	0.00% (0.00%)	0.00%	0.00%
	Passengers	0.00% (0.03%)	0.00%	0.00%
Up to 30 mph Rigid Barrier, 0 and ± 30 Degree Belted 50th Percentile Male	Drivers	0.00% (0.00%)	0.00%	0.00%
	Passengers	0.00% (0.00%)	0.00%	0.00%
20 to 30 mph, Rigid Barrier Unbelted 5th Percentile Female*	Drivers	0.00% (0.00%)	3.51%	0.06%
	Passengers	0.00% (0.00%)	2.39%	1.57%
Up to 30 mph, Rigid Barrier Belted 5th Percentile Female	Drivers	0.00% (0.00%)	3.05%	0.01%
	Passengers	0.00% (0.00%)	0.27%	0.00%
Up to 25 mph, Offset Belted 5th Percentile Female	Drivers	0.00% (0.00%)	6.19%	0.00%
	Passengers	0.61% (4.92%)	1.22%	0.00%
Up to 35 mph, Belted 50th Percentile Male	Drivers	0.01% (0.27%)	0.00%	0.00%
	Passengers	0.01% (0.43%)	0.00%	0.00%

* Results were based on unrestrained tests and those failed restrained tests.
Note: Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.

Table VI-5-B
Percentage Point Reduction of MAIS 2-5 Injury
Probability for Improved Occupant Protection From High Speed Crash Tests

Type of Tests		Front-Outboard Occupant MAIS 2-5 Injuries		
		Head	Neck(Nij)	Chest(CTI)
20 to 30 mph Rigid Barrier, 0 and ± 30 Degree Unbelted 50th Percentile Male	Drivers	0.00% (0.00%)	0.00%	0.00%
	Passengers	0.36% (0.14%)	0.00%	0.00%
Up to 30 mph Rigid Barrier, 0 and ± 30 Degree Belted 50th Percentile Male	Drivers	0.00% (0.00%)	0.00%	0.00%
	Passengers	0.00% (0.00%)	0.00%	0.00%
20 to 30 mph, Rigid Barrier Unbelted 5th Percentile Female*	Drivers	0.00% (0.00%)	8.98%	1.57%
	Passengers	0.00% (0.00%)	5.36%	2.07%
Up to 30 mph, Rigid Barrier Belted 5th Percentile Female	Drivers	0.00% (0.00%)	7.40%	0.27%
	Passengers	0.00% (0.00%)	0.81%	0.28%
Up to 25 mph, Offset Belted 5th Percentile Female	Drivers	0.00% (0.00%)	11.88%	0.00%
	Passengers	8.41% (3.39%)	3.44%	0.00%
Up to 35 mph, Belted 50th Percentile Male	Drivers	1.05% (0.47%)	0.00%	0.70%
	Passengers	1.55% (0.69%)	0.00%	0.10%

* Results were based on unrestrained tests and those failed restrained tests.
Note: Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.

All estimates in Tables VI-5-A and VI-5-B are based on the assumption that all vehicles in the fleet are equipped with pre-MY 1998 air bags and there are no changes in occupant demographics, driver/passenger behavior, belt use, child restraint use, or the percent of children sitting in the front seat. The analysis uses the most current year of crash data (1997 GES, 1997 FARS, and 1993-1997 CDS) and 1997-1998 SCI cases to derive the potential target populations that would be impacted by advanced air bags. This somewhat takes into account the current impacts of factors such as "public safety campaigns" and "air bag warning labels" that have effects on occupant safety. However, the analysis does not estimate the further potential impacts if certain trends continue. It also assumes that the sensors and other mechanical/electronic technologies are 100 percent accurate and reliable in performing their required functions (if these systems were 99.99 percent effective, it would make no difference numerically in the estimates since the target populations are not large enough to make a difference of even one life). Further, it is assumed that sales volumes of vehicles tested represent their proportional distribution of involvement in crashes. Finally, the analysis examines only a 54 pound weight sensor for RFCSS and children.

C. Benefit Estimates

Minimize Risks of Air Bag Induced Fatalities

1. Infants in RFCSS

As indicated in Table VI-3, if all vehicles in the fleet were equipped with pre-MY 1998 air bags, a total of 18 infants in RFCSS would be fatally injured by air bags annually. From a telephone survey of the public on child safety seat issues that NHTSA conducted between November 1996 and January 1997, 85 percent said they put the safety seat in the back seat, a 7 percentage point increase over 1994[4]. The analysis of FARS (Table II-9, Chapter II) data showed that the percent

[4] 1996 Motor Vehicle Occupant Safety Survey, Volume 5: Child Safety Seat Report, DOT HS 808 634, December, 1997.

of infants and toddlers riding in the back seat of cars with dual air bags has increased substantially since 1996 - from about 70 percent to about 90 percent. The infant fatality numbers in 1997-1998, which are the basis for the 18 fatalities in the target population, may reflect this changing behavior. Therefore, the analysis doesn't make a further adjustment and uses the projected 18 infants in RFCSS as the target population.

The test for RFCSS includes two alternative options: suppression and low risk deployment.

Suppression

The suppression test would require that the air bag be shut off whenever a RFCSS is present. Suppression systems could be equipped with weight sensors, ultrasound, or infrared which would detect a RFCSS in the vehicle and shut off the air bag. A system that passes the test and is nearly 100 percent effective would eliminate the 18 RFCSS fatalities annually. In the case of a RFCSS, a static suppression system would be sufficient. For example, a 54-pound-limit static suppression system would suppress inflation of the air bag when the front passenger, and child safety seat, weighs 54 pounds or less. This particular static weight suppression system could prevent all 18 RFCSS fatalities. The dynamic air bag suppression system would not be needed.

Mercedes and BMW have MY 1998 production systems based on a 26 pound suppression threshold that could minimize air bag induced RFCSS fatalities. However, their sales are not enough to reduce the estimate (18*0.985=17.7, rounds to 18).

Low Risk Deployment

All the infants killed by air bags suffered head injuries. Thus, the HIC 15 value is a reasonable injury criterion to estimate the probability of an infant being fatally injured by an air bag. The agency proposes HIC 15=390 as head ICPL for infants. At 390 HIC, the probability of an infant being killed is 0.02 percent measured by Prasad/Mertz and 1.7 percent measured by lognormal curves. The estimated reduction rates for the low risk deployment were based on the HIC values from FMVSS 213 tests on 12-month old CRABI. If a low risk deployment system met 390 HIC, and this was sufficiently protective for infants, it would prevent 17-18 infant fatalities by assuming the low risk deployment would eliminate 92.19 to 99.93 percent (Table VI-4-A) of infant fatalities.

One of the systems that could be designed to pass the low risk deployment test, for example, is the multi-stage inflation system based on crash severity and belt use. As described in Table VI-2, the analysis assumes multi-stage air bags would not be inflated if the impact speed is less than 18 mph for belted occupants and the first stage air bag would be inflated with lower force. The first stage low level deployment air bag might be able to meet the low risk deployment tests. For infants, the system must pass at all inflation levels, since the agency is also concerned about infants in RFCSS in high speed crashes (not just those in the SCI cases at 25 mph delta V or less). The second stage power of the multi-stage system may fail the low-risk test for infants. This may also be difficult to accomplish with mid-mounted bags. Systems with top-mounted[5] bags may be

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[5] Top-mounted air bags deploy up towards the windshield first and then back towards the occupant. A top-mounted air bag may go over a RFCSS and possibly could meet the injury criteria. A mid-mounted air bag deploys back towards the child restraint initially and it would be very difficult to meet the injury criteria with this type of system, with current air bag technology.

more likely to pass than mid-mount bags at higher inflation levels. A total of 13 RFCSS fatalities occurred in crashes with speeds below 18 mph. If the multi-stage system successfully met the test requirements for infants, these 13 RFCSS belted fatalities would all be prevented by this system. If the first stage deployment met the HIC 15 390 requirement, then 5 RFCSS fatalities would be prevented in the first deployment stage. Altogether, the multi-stage inflation system based on crash severity could save 18 infant lives assuming the first stage deployment power passed the low risk deployment test. Because all the RFCSSs with infants in them weigh less than 30 pounds, a multi-stage inflation system equipped with a 54-pound weight sensor would also prevent all 18 infant fatalities if the system meets the injury values.

In summary, as shown in Table VI-6, the rear-facing child safety seat test would have the potential to prevent 18 infant fatalities either by suppression or by the first stage meeting low risk deployment.

Table VI-6
Estimated Fatality Reduction Benefits of Optional Tests For Rear Facing Child Fatalities

Air Bag Systems	**Lives Saved Per Year**
Suppression System	18
Low Risk Deployment System	17-18
- Multi-Level Inflation System*	18
- Multi-Level Inflation System with a 54 Pound Weight Suppression Option*	18

* The first stage passed the low risk deployment test.

2. Children (1 to 12 Years Old)

As shown in the Table VI-3, assuming all vehicles in the on-road fleet have pre-MY 1998 air bags, a total of 105 children would be projected to be killed by air bags annually. The out-of-position tests using the 3-year-old dummy and the 6-year-old dummy together address the air bag-children interaction scenario. Suppression and low risk deployment testing are options to minimize air bag risk.

Suppression

The "suppression with child present" test would require the system to shut off the air bag if the sensors detect a child and ideally also would prevent all 105 child fatalities. However, the suppression test uses only 3- and 6-year-old dummies which do not represent children of all ages up to 12 years old. Here, the analysis uses 54 pounds as the threshold to differentiate children because the instrumented 6-year-old dummy weighs 54 pounds. About 83 of the 105 child fatalities are estimated to weigh 54 pounds or less. Eight (10 percent) of these children are estimated to be sitting on the lap of an adult passenger and thus would not be identified as children by a weight sensor. For this reason, the "suppression when child present" test is assumed to save only 75 (=83-8) children. However, manufacturers could possibly use a higher weight threshold (e.g., 66 pounds) or more advanced sensors to cover more children without improperly suppressing the air bag when a 5th percentile female is present. If more sophisticated sensor technologies were used and they would accurately detect children, the improved air bag systems could potentially save up to 97 (=105-8) children.

The "suppression when out-of-position" test would require that the system shut off the air bag if the proximity sensors detect that an occupant is too close to the air bag. How effective the system is depends upon whether it is a static or dynamic system. A static system would only suppress when an occupant starts in a "risk zone." A dynamic "suppression when out-of-position" system, if it works perfectly to detect out-of-position children would prevent all of these 105 child fatalities. About 13 percent of children were unbelted and weighed more than 54 pounds. These children would more likely be benefitted only by the dynamic suppression system.

Low Risk Deployment

Reduction rates were based on the agency's out-of-position tests with a 6 year old dummy right on the air bag module. As described in the methodology section, children in the SCI cases all suffered severe head and neck injury; therefore only the HIC/Nij value combination is used to assess the benefits. Applying the fatality reduction rates shown in Table VI-4-A to the 105 target child population, an air bag system passing the low risk deployment would eliminate 95-96 child fatalities. Table VI-7 presents the child fatalities that would be reduced if an air bag passes the low risk deployment test.

Table VI-7
Estimated Fatality Reduction Benefits of Low Risk Deployment Test
Children 1-12 Years Old

Target Population	105
Fatality Reduction Rate*	0.9034 - 0.9122
Lives Saved	95 - 96

* From Table VI-4-A.

The multi-stage inflation system considered in this analysis could potentially pass the low risk deployment at the first stage deployment level. To estimate the benefits that accrue from the multi-stage inflation system based on crash severity, the child data are rearranged by inflation stages corresponding to that of the system and by two different weight categories as shown in Table VI-8. These fatalities all occurred at low-to-moderate speeds (belted ≤ 30 mph, and unbelted ≤ 25 mph); hence there would be no incidents at stage 2.

Table VI-8
Target Fatal Population By Weight and Multi-Stage Air Bag Inflation Stages
Children 1-12 Years Old

Weight	Suppression*	Stage 1	Stage 2	Total
≤ 54 lbs	61	22	0	83
> 54 lbs	15	7	0	22
Total	76	29	0	105

Source: Projected number from the Special Crash Investigation cases as January 1, 2000
* See Table VI-2 for the definition of stage groups.

The multi-stage inflation system by crash severity would prevent 76 child fatalities by suppression. By applying the fatality reduction rate to the target population at the first stage, low level deployment, the system would prevent another 26 child fatalities. In total, the system could prevent 102 child fatalities. Table VI-9 presents the benefits of this system for children.

If the multi-stage system were equipped with a 54-pound weight sensor, 98 (see Table VI-8) children would be saved by suppression either by crash severity or by weights. Note that 8 of those children sat on an adult's lap were in crashes with impact speeds less than 14 mph. These children would be saved by suppression based on crash severity and thus included in those 98 children saved in the suppression stage. The first stage deployment, if it met the low risk deployment test, would prevent another 6 child fatalities. The multi-stage system with a 54-pound weight suppression system would prevent 104 child fatalities. Table VI-10 summarizes the benefits of the system with a 54-pound weight suppression sensor.

Table VI-9
Estimated Fatality Reduction Benefits of A Multi-Stage System
Children 1-12 Years Old

Lives Saved at the Suppression Stage[1]	76
The First Stage Deployment	
Target Population	29
Fatality Reduction Rate[2]	0.9034 - 0.9122
Lives Saved	26 - 26
Total Lives Saved	102 - 102

1. From Table VI-8
2. From Table VI-4-A, low risk deployment.

Table VI-10
Estimated Fatality Reduction Benefits of A Multi-Stage System With a 54-Pound Weight Sensor
Children 1-12 Years Old

Lives Saved by the Suppression Options (by crash severity or a 54 pound limit)[1]	98
First Stage, Low Level Deployment	
Target Population with Weight > 54 Pounds	7
Fatality Reduction Rate[2]	0.9034 - 0.9122
Lives Saved	6 - 6
Total Lives Saved	104 - 104

1. From Table VI-8
2. From Table VI-4-A, low risk deployment

3. Close Proximity Adults

If all vehicles in the fleet were equipped with pre-MY 1998 air bags, a total of 64 adults (46 drivers and 18 passengers) would be killed annually by the air bags because they were too close to the air bag module when it deployed. Compared to their percent of the population, small stature adults (shorter than or equal to 64 inches) and older adults are disproportionately represented in adult fatalities attributed to air bags. This is because short stature or older drivers (especially females) are more likely to sit close to the steering wheel and are more prone to injury at a given force or acceleration level, and therefore are more at risk. The tests using 5th percentile dummies and accompanying ICPLs provide the best safety measures for these adults in close proximity to the air bag. Virtually all adults weigh more than 60 pounds; thus the 54-pound weight suppression system on the passenger side would have no effect on these adults and would not accrue any benefits for adult passengers. Benefits are estimated separately for drivers and passengers.

Drivers

Of the 64 adults who would be killed by air bags annually, 46 are drivers. Fifteen (33 percent) of these drivers are unrestrained (including drivers with unknown belt usage); thirty-eight (82 percent) are small stature adults with heights of 64 inches or shorter; seventeen (36 percent) are 65 years and older.

Dynamic Suppression

If the dynamic suppression-when-out-of-position test worked perfectly, it would prevent all 46 driver fatalities because the air bags would shut off if they detected out-of-position drivers in these low speed crashes. Manufacturers do not appear to be considering dynamic out-of-position systems for drivers currently. (Static suppression is not an option for drivers in the final rule.)

Low Risk Deployment

Based on the fatality reduction rate shown in Table VI-4-A, the test would eliminate 52.23 percent of close proximity driver fatalities, i.e., 24 (=46*0.5223) driver fatalities could be prevented. The multi-stage system and systems with modified fold patterns or inflator might meet the low-risk deployment test.

Up to 25 MPH Offset Belted Test

This analysis also considers these close-proximity adults to be out-of-position because of late air bag firing. One reason for the 25 mph offset test is to improve the air bag fire time, and thus save these drivers. The reduction rate (38.37 percent) for the 25 mph offset test was based on the TC 25 mph offset crash tests with a belted 5th percentile female dummy. Because this test is intended to improve sensor technology, the reduction is applied to all the at-risk adult drivers. The 25 mph offset test would save 18 (=46*0.3837) drivers.

It is assumed that the hypothetical multi-level inflation air bag system could pass the low risk deployment at the first stage of deployment. To estimate the benefits that accrue from the multi-stage inflation system based on crash severity, drivers are classified by height and air bag inflation stages corresponding to those of the system as shown in Table VI-11. Because these fatalities all occurred at low-to-moderate speeds (both belted and unbelted ≤ 25 mph), there were no incidents occurring at stage 2.

Table VI-11
Target Population By Multi-Stage Air Bag Inflation Stages
Drivers in Frontal Crashes

Driver Groups	Suppression*	Stage 1	Stage 2	Total
Represented by 50th Percentile Male	12	6	0	18
Represented by 5th Percentile Female	22	6	0	28
Total	34	12	0	46

Source: Projected number from the Special Crash Investigation cases as January 1, 2000
* See Table VI-2 for the definition of the stage groups.

The suppression and low level depowering features (stage 1) of the system would prevent a total of 40 (see Table VI-12) driver fatalities based on the assumption that low power deployment would prevent 52.23 percent of driver fatalities and the system passes the low risk deployment.

Table VI-12
Estimated Fatality Reduction Benefits of A Multi-Stage System
Drivers in Close Proximity

Lives Saved by the Suppression Stage[1]	34
First Stage Deployment (passed low risk deployment)	
Target Population	12
Fatality Reduction Rate[2]	0.5223
Lives Saved	6
Total Lives Saved	40

1. From Table VI-11
2. From Table VI-4-A

Passengers

There would be a projected total of 18 adult passengers killed by air bags if the full fleet were equipped with pre-MY 1998 air bags. Fifteen (83 percent) of the 18 are small stature adults. Twelve (67 percent) of them are 65 years or older.

Suppression

The suppression when out-of-position test would save all 18 adult passenger fatalities because air bags would not be deployed if they detected an out-of-position passenger.

Low Risk Deployment

The reduction rates for the low risk deployment were assumed to be identical to those of children. The low risk deployment test would prevent 16 adult passenger fatalities assuming that the low risk deployment test would eliminate 90.34 to 91.22 percent of fatalities. See Table VI-13.

Table VI-13
Estimated Fatality Reduction Benefits of Low Risk Deployment Test
Adult Passengers in Close Proximity

Target Population	18
Fatality Reduction Rate[1]	0.9034 - 0.9122
Lives Saved	16 - 16

1. From Table VI-4-A.

Up to 25 MPH Offset Belted Test

The reduction rate (13.26 percent) of this test for passengers was based on TC 25 mph offset belted crash tests on 5th percentile females. The offset belted test would prevent 2=(18*13.26) adult passenger fatalities.

The multi-level inflation air bag system may pass the low risk deployment at the first stage deployment level. The multi-stage inflation system based on crash severity would save a total of 17 passengers as shown in Table VI-14.

Table VI-14
Estimated Fatality Reduction Benefits of A Multi-Stage System
Adult Passengers in Close Proximity

Lives Saved by the Suppression Stage	9
First Stage, Low Level Deployment	
Target Population	9
Fatality Reduction Rate*	0.9034 - 0.9122
Lives Saved	8 - 8
Total Lives Saved	17 - 17

* From Table VI-4-A.

2. Minimize Risks of Air Bag Induced MAIS 3-5 Injuries

Air bag-induced MAIS 3-5 injuries were projected from at-risk fatalities, therefore, all the descriptive statistics (e.g., percent distribution by age, weights, and etc.) were based on fatalities for at-risk groups. In addition, all the assumptions and limitations for a specific group or a test that were discussed in the fatality benefits also apply to injury benefits. Therefore, the following injury benefit discussions for each test and air bag system do not repeat these statements

1. **Infants in RFCSS**

As indicated in Table VI-3, if all vehicles in the fleet were equipped with pre-MY 1998 air bags, a total of 9 infants in RFCSS would be seriously injured by air bags annually.

Suppression

A suppression system that passes the suppression test and is nearly 100 percent effective would eliminate the 9 RFCSS MAIS 3-5 injuries annually. In the case of a RFCSS, a static suppression system would be sufficient. For example, a 54-pound static suppression system would suppress inflation of the air bag when the front passenger plus the child safety seat weighs 54 pounds or less. This particular static weight suppression system could prevent all 9 RFCSS MAIS 3-5 injuries.

Mercedes and BMW have MY 1998 production systems based on a 26 pound suppression threshold that could prevent air bag induced RFCSS MAIS 3-5 injuries. However, their sales are not enough to reduce the estimate (9*0.985=8.9, rounds to 9).

Low Risk Deployment

As discussed in the RFCSS fatality section, the HIC 15 value is the only injury criterion used to estimate the probability of an infant being seriously injured by an air bag. The estimated reduction rates for the low risk deployment were based on the HIC 15 values from FMVSS 213 tests on 12-

month old CRABI. The MAIS 3-5 injury reduction rate (Table VI-4-B) is 60.15 percent measured by Prasad/Mertz and 55.78 percent measured by lognormal curves. A low risk deployment system, as shown in Table VI-15, would reduce 5 infant MAIS 3-5 injuries.

Table VI-15
Estimated MAIS 3-5 Injury Reduction Benefits of Low
Risk Deployment Test RFCSS

Target Population	9
Injury Reduction Rate[1]	0.5578 - 0.6015
Injuries Reduced	5 - 5

1. From Table VI-4-B.

The multi-stage inflation system would reduce 6 infant MAIS 3-5 injuries by the suppression stage. Altogether, as shown in Table VI-16 the multi-stage inflation system based on crash severity could prevent 8 infant MAIS 3-5 injuries assuming that the first stage power passed the low risk deployment test. Because all the RFCSSs and infants weigh less than 30 pounds, a multi-stage inflation system equipped with a 54-pound weight sensor would also prevent all 9 infant MAIS 3-5 injuries.

Table VI-16
Estimated Fatality Reduction Benefits of A Multi-Stage System
Rear Facing Child MAIS 3-5 Injuries

Injury Reduced by the Suppression Options (by Crash Severity)	6
First Stage, Low Level Deployment	
Target Population	3
Injury Reduction Rate[1]	0.5578 - 0.6015
Injury Reduced	2 - 2
Total Lives Saved	8 - 8

1. From Table VI-4-B, low risk deployment

In summary, as shown in Table VI-17, the rear-facing child safety seat test would have the potential to prevent 9 infant injuries by suppression, 5 injuries by low risk deployment, and 8 injuries by the multi-level inflation system.

Table VI-17
Estimated Injury Reduction Benefits of Optional Tests For Rear Facing Child MAIS 3-5 Injuries

Air Bag Systems	MAIS 3-5 Injuries Reduced Per Year
Suppression System	9
Low Risk Deployment System	5
- Multi-Level Inflation System	8
- Multi-Level Inflation System with a 54 Weight Sensor Options	9

2. Children (1 to 12 Years Old)

A total of 200 children would be projected to be seriously injured by air bags annually. Suppression and low risk deployment testing are options to minimize air bag risk.

Suppression

The "suppression with child present" test would require the system to shut off the air bag if the sensors detect a child and ideally also would prevent all 200 child MAIS 3-5 injuries. Of these 200 children, 158 weighed less than or equal to 54 pounds. Of these 158, 16 children are estimated to be sitting on an adults' lap when the crash occurred and these children would not be detected as a child weighing less than 54 pounds. The 54 pound suppression options would reduce 142 (=158-16) child serious injuries. If manufacturers voluntarily install a higher weight threshold (e.g., 66 pounds) suppression system, it would cover more children without improperly suppressing the air bag when a 5th percentile female is present. Or, if more sophisticated sensor technologies were used and they would accurately detect children, the improved air bag systems could potentially prevent up to 184 (=200-16) child MAIS 3-5 injuries.

The "suppression when out-of-position" test would require that the system shut off the air bag if the proximity sensors detect that a child is too close to the air bag; if it works perfectly it would prevent all of these 200 child MAIS 3-5 injuries.

Low Risk Deployment

As described in the fatal benefit section, only the HIC/Nij value combination is used to assess the benefits. Applying the injury reduction rates as shown in Table VI-4-B to the 200 target child injury population, an air bag system passing the low risk deployment test would eliminate 154 air bag-induced injuries. Table VI-18 presents the child injuries that would be reduced if an air bag passes the low risk deployment test.

Table VI-18
Estimated MAIS 3-5 Injury Reduction Benefit of Low Risk Deployment Test
Children 1-12 Years Old

Target MAIS 3-5 Injury Population	200
Injury Reduction Rate*	0.7683 - 0.7710
Injuries Reduced	154 - 154

* From Table VI-4-B.

To estimate the benefits that accrue from the multi-stage inflation system based on crash severity, the child data are rearranged by inflation stages corresponding to that of the system and by two different weight categories as shown in Table VI-19. Note that the injury distribution was based on the distribution of fatalities. These injuries all occurred at low-to-moderate speeds (belted ≤ 30 mph, and unbelted ≤ 25 mph); hence there were no incidents at stage 2.

Table VI-19
Target MAIS 3-5 Injury Population By Weight and Multi-Stage Air Bag Inflation Stages
Children 1-12 Years Old

Weight	Suppression*	Stage 1	Stage 2	Total
≤ 54 lbs	117	41	0	158
> 54 lbs	28	14	0	42
Total	145	55	0	200

Source: the Special Crash Investigation cases as January 1, 2000 and 1993-1998 CDS.
* See Table VI-2 for the definition of stage groups.

The multi-stage inflation system by crash severity would reduce 145 child MAIS 3-5 injuries by suppression. As discussed previously, by applying the injury reduction rate (Table VI-4-B) to the target population at the first stage, low level deployment, the system would prevent another 42 child injuries. In total, the system could reduce 187 child MAIS 3-5 injuries. Table VI-20 presents the injury benefits of this system for children.

Table VI-20
Estimated MAIS 3-5 Injury Benefits of A Multi-Stage System
Children 1-12 Years Old

Injuries Reduced at the Suppression Stage[1]	145
The First Stage Deployment	
Target Population	55
Injury Reduction Rate[2]	0.7683 - 0.7710
Injuries Reduced	42 - 42
Total Injuries Reduced	187 - 187

1. From Table VI-19
2. From Table VI-4-B, low risk deployment.

If the system were equipped with a 54-pound weight sensor, 186 child injuries would be prevented by suppression either by crash severity or by weights (28 by crash severity; 158 by the 54 pound weight suppression option). The first stage deployment, if it met the low risk deployment test, would prevent another 11 child injuries. In total, the multi-stage system with a 54-pound weight suppression system would prevent 197 child MAIS 3-5 injuries. Table VI-21 summarizes the benefits of the system with a 54-pound weight suppression sensor.

3. Close Proximity Adults

If all vehicles in the fleet were equipped with pre-MY 1998 air bags, a total of 53 adults would be seriously injured by the air bags because they were too close to the air bag module when it deployed. Of the 53 adults MAIS 3-5 injuries, 38 were drivers and 15 were front-outboard passengers.

Table VI-21
Estimated MAIS 3-5 Injury Reduction Benefits of A Multi-Stage System
With a 54-Pound Weight Sensor
Children 1-12 Years Old

Injuries Reduced by the Suppression Options (by crash severity or a 45 pound limit)[1]	186
First Stage, Low Level Deployment	
Target Population with Weight > 54 Pounds	14
Injury Reduction Rate[2]	0.7683 - 0.7710
Injuries Reduced	11 - 11
Total Injuries Reduced	197 - 197

1. From Table VI-8
2. From Table VI-4-B, low risk deployment

Drivers

Dynamic Suppression

If the dynamic suppression when out-of-position test worked perfectly, it would reduce all 38 driver injuries because the air bags would shut off if they detected out-of-position drivers in these low speed crashes. Manufacturers are not considering dynamic out-of-position systems currently.

Low Risk Deployment

Based on the injury reduction rate shown in Table VI-4-B, the test would eliminate 51.90 percent of close proximity driver MAIS 3-5 injuries, i.e., 20 (=38*0.5190) driver injuries would be reduced. The multi-stage system and systems with modified fold patterns or inflator might meet the low-risk deployment test.

Up to 25 MPH Offset Belted Test

The up to 25 mph offset tests would eliminate 47.82 percent of close proximity driver MAIS 3-5 injuries, i.e., 18 (=38*0.4782) driver injuries would be reduced.

For the multi-stage inflation system based on crash severity, driver injuries are tabulated by height and air bag inflation stages corresponding to those of the system as shown in Table VI-22. Because these injuries all occurred at low-to-moderate speeds (both belted and unbelted ≤ 25 mph), there were no incidents occurring at stage 2.

Table VI-22
Target Driver MAIS 3-5 Injury Population By Multi-Stage Air Bag Inflation Stages

Driver Groups	Suppression*	Stage 1	Stage 2	Total
Represented by 50th Percentile Male	10	5	0	15
Represented by 5th Percentile Female	18	5	0	23
Total	28	10	0	38

Source: the Special Crash Investigation cases as January 1, 2000; 1993-1998 CDS
* See Table VI-2 for the definition of the stage groups.

The suppression and low level depowering features (stages 1) of the system would reduce a total of 33 (see Table VI-23) driver MAIS 3-5 injuries based on the assumption that low power deployment would prevent 51.90 percent of driver injuries and the system passes the low risk deployment tests.

Table VI-23
Estimated MAIS 3-5 Injury Reduction Benefits of A Multi-Stage System
Drivers in Close Proximity

Injuries Reduced by the Suppression Stage[1]	28
First Stage Deployment (passed low risk deployment)	
Target Population	10
Injury Reduction Rate[2]	0.5190
Injuries Reduced	5
Total Injuries Reduced	33

1. From Table VI-23
2. From Table VI-4-B

Passengers

There would be a projected total of 15 adult passenger MAIS 3-5 injuries.

Suppression

The suppression when out-of-position test would prevent all 15 adult passenger injuries because air bags would not be deployed if they detected an out-of-position passenger.

Low Risk Deployment

The low risk deployment test would prevent 12 (=15*0.7683 or 15*0.7710) adult passenger MAIS 3-5 injuries assuming that low risk deployment test would eliminate 76.83 to 77.10 percent of injuries.

Up to 25 MPH Offset Belted Test

The up to 25 mph offset tests would prevent 3 (=15*0.1883) adult passenger MAIS 3-5 injuries assuming that the low risk deployment test would eliminate 0.1883 percent of injuries.

The multi-level inflation air bag system may pass the low risk deployment at the first stage deployment level. The multi-stage inflation system based on crash severity and belt use would prevent 13 of these passenger injuries as shown in Table VI-24

Table VI-24
Estimated MAIS 3-5 Injury Reduction Benefits of A Multi-Stage System
Adult Passengers in Close Proximity

Injuries Reduced by the Suppression Stage	7
First Stage, Low Level Deployment	
Target Population	8
Injury Reduction Rate*	0.7683 - 0.7710
Injuries Reduced	6 - 6
Total Injuries Reduced	13 - 13

* From Table VI-4-B.

3. Summary of Benefits From At-Risk Groups

There is some question about the reliability of suppression and low risk deployment countermeasures and further development of these countermeasures is necessary. To the extent that these systems are not as reliable as assumed, children and small adults would continue to be at risk. Table VI-25 summarizes the benefits from at-risk groups.

Table VI-25
Fatality and MAIS 3-5 Injury Benefits From At-Risk Groups

	At-Risk Groups				
Fatalities	**Infants**	**Children**	**Adult Passengers**	**Drivers**	**Total**
Baseline Target Population	18	105	18	46	187
Estimated Lives Saved by Suppression	18	75	0*	0*	93
Estimated Lives Saved by Low Risk Deployment	17-18	95-96	16	24	152-154
Estimated Lives Saved by Multi-Stage Inflation System	18	102	17	40	177
Estimated Lives Saved by Multi-State Inflation System + a 54-Pound Weight Suppression	18	104	17	40	179
MAIS 3-5 Injuries					
Baseline Target Population	9	200	15	38	262
Estimated Injuries Reduced by Suppression	9	142	0*	0*	151
Estimated Injuries Reduced by Low Risk Deployment	5	154	12	20	191
Estimated Injuries Reduced by Multi-Stage Inflation System	8	187	13	33	241
Estimated Injuries Reduced by Multi-State Inflation System + a 54-Pound Weight Suppression	9	197	13	33	252

* Not proposed test for this group.

Benefits From Improved Occupant Protection From High Speed Crash Tests

1. Fatalities

As described in the method section, the reduction percentage is calculated for each test that failed the proposal injury values. Benefits are derived by applying the reduction percentages to the appropriate target population as shown in Table VI-26. The analysis gave precedence to head injuries if an occupant had a maximum head, chest injury, and neck injury at the same AIS level.

Table VI-26
Target Populations for Improved Occupant Protection From High Speed Crash Tests
Front-Outboard Adult Occupant Fatalities in Frontal Crashes

	Fatalities Represented by 50th Percentile Male			Fatalities Represented by 5th Percentile Female			Fatalities Potentially Impacted by Improving Sensor Algorithm		
	Head	Neck	Chest	Head	Neck	Chest	Head	Neck	Chest
Drivers	3,759	1,524	3,759	749	375	687	680	294	680
Belted	1,242	504	1,242	248	124	227	225	97	225
Unbelted	2,517	1,020	2,517	501	251	460	455	197	455
Passengers	958	176	763	313	225	613	192	63	207
Belted	314	58	250	102	74	200	63	20	68
Unbelted	644	118	513	211	151	413	129	43	139
Total	4,717	1,700	4,522	1,062	600	1,300	872	357	887
Belted	1,556	562	1,492	350	198	427	288	117	293
Unbelted	3,161	1,138	3,030	712	402	873	584	240	594

Source: 1993-1997 CDS; 1997 FARS
Note: Fatalities were derived from 1993-1997 CDS and adjusted to 1997 FARS level.

The fatal reduction percentages shown in Table VI-5-A are applied to the population in Table VI-26. Table VI-27 shows the fatality reduction benefits. An air bag that passes the 30 mph, unbelted 5th percentile female test would save 19 lives, while the belted test would save 4 lives.

The 25 mph offset, belted 5th percentile female test would save 20 to 28 lives.

Note that tests with no additional benefits beyond those already achieved (total 3,253 lives annually) from Pre-MY 1998 air bags are shown as 0 in Table VI-27. For example, the 0 benefits for the 30 mph rigid barrier tests with 50th percentile males indicates that this type test would not accrue additional benefits. All vehicles tested with 50th percentile male dummies met the new neck injury criteria and the other new ICPLs.

1.2 Fatality Impact of Rigid Barrier 25 mph Unbelted Tests

This section estimates the safety impacts of air bags that are designed to meet the 25 mph rigid barrier unbelted perpendicular and ± 30 degree oblique tests. We cannot estimate the most likely difference between setting the unbelted tests at the two different levels, because it depends on how the manufacturers would meet the alternative performance requirements. NHTSA believes that it is unlikely that vehicle manufacturers will significantly depower their air bags compared to the MY 1998-2000 fleet. Vehicle manufacturers have not depowered their air bags so much that they minimally comply with the sled test. Crash tests and field experience to date with vehicles certified to the sled test have indicated that there has not been a loss of frontal crash protection compared to pre-MY 1998 vehicles. If the manufacturers keep the same level of power as they currently have in MY 1998-2000, even with a 25 mph unbelted test requirement, then the difference in actual benefits between the two test speeds would be small or even eliminated.

At the same time, we cannot rule out the possibility that air bags will be significantly depowered. To account for this possibility, we calculated a "worst case" scenario comparing the benefits at the minimum performance requirements of each speed.

Table VI-27
Fatalities Reduced by Test Types for
Improved Occupant Protection From High Speed Crash Tests

		Head	Neck	Chest	Total
20 to 30 mph, Rigid Barrier, 0 and ± 30 Degree Unbelted 50th Percentile Male	**Drivers**	0 (0)	0	0	0* (0*)
	Passengers	0 (0)	0	0	0* (0*)
	Total	0 (0)	0	0	0* (0*)
Up to 30 mph, Rigid Barrier, 0 Degree Belted 50th Percentile Male	**Drivers**	0 (0)	0	0	0* (0*)
	Passengers	0 (0)	0	0	0* (0*)
	Total	0 (0)	0	0	0* (0*)
20 to 30 mph, Rigid, 0 Degree Unbelted 5th Percentile Female**	**Drivers**	0 (0)	9	0	9 (9)
	Passengers	0 (0)	4	6	10 (10)
	Total	0 (0)	13	6	19 (19)
Up to 30 mph, Rigid Barrier, 0 Degree Belted 5th Percentile Female	**Drivers**	0 (0)	4	0	4 (4)
	Passengers	0 (0)	0	0	0 (0)
	Total	0 (0)	4	0	4 (4)
25 mph, Offset belted 5th Percentile Female	**Drivers**	0 (0)	18	0	18 (18)
	Passengers	1 (9)	1	0	2 (10)
	Total	1 (9)	19	0	20 (28)

* No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
** Results were based on unrestrained tests and those failed the restrained tests.
Note: Parenthetical values based on lognormal HIC curve, Non parenthetical values based on Prasad/Mertz HIC curve.

To calculate the "worst case" scenario, two different approaches were examined. Both of these approaches derive point estimates. These point estimates do not necessarily define the full range of possible outcomes due to uncertainty regarding both data and assumptions under each method. These approaches reflect the fact that current vehicle fleets have not yet been redesigned based on a 25 mph test requirement. Instead, most vehicles are designed based on the 30 mph frontal barrier test required on all pre-MY1998 vehicles. If manufacturers were to redesign for 25 mph tests during their normal design cycle, the resulting vehicles could perform at a level that maximizes their performance in the 25 mph tests, rather than in the 30 mph frontal barrier test.

The first approach examined existing data broken out by delta-v. Target populations (unrestrained front-outboard occupant potential fatalities) and lives saved were computed for 4 different delta-v categories. These data produced estimates of different effectiveness rates for each speed category. Due to the sample size concerns of air bag cases and the vast unknown delta-v, MAIS 3+ injuries (age 13 and older) from 1993-1998 CDS were used as a surrogate for adult fatalities to estimate the effectiveness of air bags by delta-v levels. This analysis reveals higher effectiveness rates for the speed groupings nearest the speed levels where testing was required in most of the on-road fleet. Current tests are conducted at 30 mph, and effectiveness is lowest for speeds under 20 and over 31 mph, and highest in the range of 21-30. If manufacturers were to design their vehicles to a 25 mph rigid barrier test, it would be the equivalent of designing them to a requirement that is at least 5 mph slower than the 30 mph frontal barrier tests that were required in pre-MY 1998 vehicles. To estimate the results of such a redesign, each speed category was reduced by 5 mph, while effectiveness rates were held constant. New target populations were then derived for each new speed category, and the resulting benefits were calculated by applying the realigned effectiveness rates to their corresponding target populations. Since the new designed air bags were assumed to affect only the unrestrained occupants in frontal crashes, the target population included only the unrestrained front-outboard adult (age 13 and older) occupant potential fatalities. Table VI-28 shows this process and its results. The calculation indicates that 252 fewer fatalities would be prevented if vehicles were designed to a 25 mph standard. Note that effectiveness rates in Table VI-28 were adjusted twice from original rates derived from 1993-1998 CDS. The overall original rate based on CDS was higher than that based on FARS. Therefore, the first adjustment was to inflate the effectiveness rate to the FARS level. The second adjustment was to inflate the air bag effectiveness specifically to unrestrained occupants. The 1998 CDS was included in the analysis to increase the sample of air bag cases.

Table VI-28
Impact of the 25 mph Rigid Barrier Test on Fatalities
Approach 1

If All Vehicles Had Pre-MY 1998 Air Bags (Passing the 30 mph, Rigid Barrier Test with 50th Percentile Males)					**If All Vehicles Had New Designed Air Bags (Passing the Existing Sled Test with 50th Percentile Males)**				
Delta V	Effective-ness	Target* Population	Lives Saved		Delta V	Effective-ness	Target* Population	Lives Saved	Benefits/ Disbenefits
0-20	0.203	1,966	399		0-15	0.203	1,148	233	
21-25	0.290	2,126	617		16-20	0.290	818	237	
26-30	0.222	2,228	495		21-25	0.222	2,126	472	
31+	0.142	6,361	903		26+	0.142	8,589	1,220	
Total		12,681	**2,414**		Total		12,681	**2,162**	**-252**

Data Source: 1993-1998 CDS, 1997 FARS
* Unrestrained front-outboard adult occupant potential fatalities based on 1997 FARS.

The second approach compared the results of 25 mph unrestrained and 30 mph unrestrained tests for matching make/model vehicles. The ratio of these test results was then used as a proxy measure for the differences that might be attained if the standard were an unrestrained 25 mph test. This is a mathematical approach that assumes that if air bags were designed to a 25 mph standard instead of a 30 mph standard, it would attain the same compliance margin at 25 mph that it actually achieved at 30 mph (400 HIC) and the 30 mph test result would be the ratio between 30 mph and 25 mph. See Table VI-29 for an example of the assumptions used in this analysis.

Table VI-29
Example of Methodology Under Approach 2

Test	Actual HIC Values for Vehicle Designed to 30 mph Test	Assumed HIC Values for Vehicle Designed to 25 mph Test
25 mph unrestrained test	200	400
30 mph unrestrained test	400	800

For vehicles designed to a 25 mph rigid barrier test, the adjustment ratios were derived based on two 1999 vehicles, the Dodge Intrepid and the Toyota Tacoma in unbelted 30 mph rigid barrier tests with 50^{th} percentile male dummies. The averaged ratio was then applied to the 30 mph rigid barrier tests on pre-MY 1998 vehicles to derive new risk probabilities. The loss in benefits were derived by comparing the new risks from higher HIC and chest g's values to the baseline measures of HIC and chest g's. Only HIC and chest g's values were used since no Nij values were recorded for pre-MY 1998 vehicles.

Under this approach, the loss in benefits could be as much as 394 lives assuming reduced benefits above 25 mph for unrestrained occupants. If benefits were assumed up to 30 mph, the loss in benefits be as much as 229 lives.

The 25 mph rigid barrier test is more stringent than a sled test, particularly when $\pm$ 30 degree oblique tests are added. The added safety benefits from a 25 rigid barrier test over a sled test would be the difference between the safety benefits of these two tests measured from the pre-MY 1998 base. Based on the crash loads that occupants received in a sled test, the sled test is considered to be roughly the equivalent of a 22 mph rigid barrier perpendicular (0 degree) crash test impact. Under this assumption, the first approach as described previously estimated that 325 fewer fatalities would be prevented if vehicles were designed to a sled test standard and that 252 fewer fatalities would be prevented if vehicles were designed to the 25 mph rigid barrier test. Therefore, air bags designed to pass the 25 mph unrestrained rigid barrier tests would save 73 (325 - 252) lives compared to air bags designed to pass the sled tests under the first approach.

Under the second approach, the loss in benefits from the sled tests could range from 295 to 508 lives (compared to 229 to 394 fewer fatalities from the 25 rigid barrier tests). Thus, 66 to 114 lives would be saved by air bags designed to the 25 mph unrestrained rigid barrier tests compared to the sled tests under the second approach.

One potential consequence of continuing to allow the generic sled test, instead of the rigid barrier with $\pm$ 30 degree oblique tests, is that manufacturers could reduce the size of the air bag. As discussed in Chapter V, certain tests would promote the use of wider air bags than other tests. For example, the 30 or 25 mph oblique test results in the dummy moving off at an angle rather than coming directly into the air bag. Thus, it promotes the use of a wider air bag. The agency believes that air bags that are smaller in width could have a negative impact on safety. The third approach estimates the impact of sled tests by examining air bag size.

One of the findings of the NHTSA evaluation of air bags[6] was that air bags were very effective in purely frontal (12 o'clock) impacts (30 percent effective), but were not as effective in partially frontal (10,11,1, and 2 o'clock) impacts (5.5 percent effective for passenger car drivers and 7 percent for light truck drivers). An update of this data for passenger car drivers, using an additional year of FARS data, shows that effectiveness decreases as the crash moves further away from direct frontal impacts - 31 percent effective at 12 o'clock, 9 percent effective in 11 and 1 o'clock impacts and 5 percent effective at 10 and 2 o'clock (the effectiveness at 11 and 1 and 10 and 2 o'clock are not statistically significant).

One of the potential countermeasures for reducing the aggressivity of air bags is to reduce the size of the air bag. If the air bag is smaller, it takes less power to inflate it. For a dual stage air bag, the smaller size of the air bag affects both inflation stages, allowing both stages to be less aggressive. This could bring air bag designs closer to meeting the low risk deployment thresholds.

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[6] "Fatality Reduction by Air Bags, Analyses of Accident Data Through Early 1996", NHTSA, DOT HS 808 470, August 1996.

The potential negative safety impact of having an air bag that is not as wide as the pre-MY 1998 air bags is that occupants could move around the air bag in impacts that are not directly frontal and strike the A-pillar or another hard point with their head. Thus, a smaller air bag could have reduced or no effectiveness in partially frontal impacts. The 30 mph oblique test, with its requirement to meet the standard "at any angle up to 30 degrees" from the perpendicular to the line of travel, helps to assure that occupants will not exceed the head injury criteria in partially frontal impacts. The sled test has no angular component and cannot address the same crash condition.

The agency examined air bag data supplied by the manufacturers as a result of a NHTSA special request for information. Of 46 driver side MY 1998 systems, 3 had decreased air bag volume (measured in liters -- an average of 18 percent) and one had increased air bag volume compared to MY 1997 air bags of the same make/model. The decrease in air bag volume was the result of decreasing the depth of the air bag.

Of 42 passenger side MY 1998 systems, 10 had decreased air bag volume (an average of 23 percent, and one had increased air bag volume). On the passenger side, most of the air bags that decreased volume decreased depth, and 8 out of 10 also decreased the width of the air bag. This shows some propensity to reduce air bag volume as a strategy to reducing the aggressiveness of air bags, particularly on the passenger side.

Based on the estimated effectiveness of air bags in pure frontals (31 percent) and in partial frontals (9 percent for 11 and 1 o'clock impacts and 5 percent for 10 and 2 o'clock impacts), an estimate can be made of the lives saved by air bags in partial frontals using the following formula and numbers from the FARS files:

$3,253 = C[1,092(1/(1-0.31) - 1) + 419(1/(1-0.09) - 1) + 245(1/(1-0.05) - 1)]$

where:

3,253 = the total estimated number of lives saved by air bags if all vehicles had air bags

C = a constant used to bring estimates made from the FARS file to date to a total fleet of air bags

1,092 = the number of fatalities in the FARS files to date that were analyzed in determining the 31 percent effectiveness in pure frontal impacts

419 = the number of fatalities in FARS files to date that were analyzed in determining the 9 percent effectiveness in 11 and 1 o'clock partial frontal impacts

245 = the number of fatalities in FARS files to date that were analyzed in determining the 5 percent effectiveness in 10 and 2 o'clock partial frontal impacts

The results of these calculations are:

$3,253 = C[491 + 41 + 13)$

$C = 5.97$

The estimated number of lives saved in pure frontals is 2,931 (5.97 x 491). Of these lives saved, 2,169 were unbelted and 762 were belted occupants; and,

The estimated number of lives saved in partial frontals is 322 [5.97 x (41 + 13)]. Of these lives saved, 245 were unbelted and 77 were belted occupants.

Thus, **if** all air bags (driver and passenger side) were changed to only provide benefits in pure frontals, the only test mode in the sled test, there could be as many as 245 unbelted lives that would not be saved by air bags per year, once all vehicles were equipped with these air bags in partial frontal impacts (about 186 drivers and 59 passengers). The 245 lives could be broken up into 186 at 11 and 1 o'clock, and 59 at 10 and 2 o'clock.

By adjusting the results in approaches 1 and 2 to be in just pure frontal (12 o'clock) crashes (adjusted by 2,931/(2,931 + 322), about 266 to 457 more unbelted lives would not be saved in pure frontal crashes by air bags designed to just pass the sled tests. Together, adding the lives not saved in approaches 1 and 2 in pure frontal crashes to the lives not saved in approach 3 in partial frontal impacts, potentially 511 to 702 (245 + 266 to 511) lives saved by pre-MY 1998 air bags would not be saved by redesigned air bags that maximize their performance in the sled test. Potentially, 282 to 308 (511 - 229 and 702 - 394) more lives could be saved by air bags designed to the 25 mph unrestrained rigid barrier tests than the lives saved by air bags designed to the sled test.

In summary, assuming there is no impact on air bag size, air bags designed to the 25 mph unrestrained rigid barrier tests could save 64 to 144 more lives than air bags designed to the sled test. Assuming air bags designed to the sled test provided no benefit in partial frontal impacts, 282 to 308 more lives could be saved by air bags designed to the 25 mph unrestrained rigid barrier $\pm$ 30 degree tests than the lives saved by air bags designed to the sled test.

1.3 Fatality Impact of 35 mph Rigid Barrier Belted Tests

This section discusses the safety impacts the 35 mph rigid barrier perpendicular belted tests on 50th males. Alternative 3 includes for the 50th percentile male dummy the 25 mph unbelted test with a 35 mph rigid barrier belted test. The high speed 35 mph belted tests would accrue additional benefits compared to a 30 mph belted test. The analysis measures pre-MY 1998 NCAP test against the injury criteria. The theory and procedures to derive the benefits were described in the methodology section (Section B). Based on 81 vehicles (MY 1996 and 1997 NCAP tests), 88 percent of the drivers and 84 percent of the passengers passed the injury criteria in a 35 mph belted rigid test. Typically, only one injury criterion was not passed and by a small margin, thus, the benefits of going from the test values down to the level of the injury criteria performance limits resulted in minimal benefits. As shown in Table VI-30, the 35 mph tests with 50th percentile males would save an estimated 0-4 additional lives[7]. While the tests with 5th percentile females (not considered for this rulemaking) would save 4 to 5 lives. Together, the tests would save about 4 to 9 lives. The approach assumes that the smallest chances possible are made to bring vehicles into compliance with a 35 mph belted test. Note that the reduction rate for the 35 mph, rigid barrier restrained tests with 5th percentile population were based on 50th males tests and those that failed the 25 mph restrained test with 5th percentile females. Estimated lives saved were derived by applying the reduction rates to the corresponding baseline population shown in Table VI-26.

[7] The benefits would be up to 8 lives if one considered a 20 percent compliance margin.

2. MAIS 2-5 Injuries

The MAIS 2-5 injury reduction percentages are shown in Table VI-5-B. Benefits are derived by applying the reduction percentages to the appropriate injury target population as shown in Table VI-31.

Table VI-30
Fatalities Reduced by the 35 MPH Rigid Barrier Tests

Reduction Rates		**Head**	**Neck**	**Chest**	**Total**
Up to 35 mph, Rigid Barrier, Belted 50th Percentile Male	**Drivers**	0.01% (0.27%)	0.00%	0.00%	
	Passengers	0.01% (0.43%)	0.00%	0.00%	
Up to 35 mph, Rigid Barrier, Belted 5th Percentile Females**	**Drivers**	0.01% (0.27%)	3.05%	0.00%	
	Passengers	0.01% (0.43%)	0.27%	0.00%	
Estimated Lives Saved					
Up to 35 mph, Rigid Barrier, Belted 50th Percentile Male	**Drivers**	0 (3)	0	0	0* (3)
	Passengers	0 (1)	0	0	0* (1)
	Total	0 (4)	0	0	0* (4)
Up to 35 mph, Rigid Barrier, Belted 5th Percentile Females**	**Drivers**	0 (1)	4	0	4 (5)
	Passengers	0 (0)	0	0	0* (0*)
	Total	0 (0)	4	0	4 (5)

* No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
** Rates were based on those vehicles failed either the 30 mph tests on 50th males or the 25 mph tests on 5th females.
Note: Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.

Table VI-31
Target Populations for Improved Occupant Protection From High Speed Crash Tests
Front-Outboard Adult Occupant MAIS 2-5 Injuries in Frontal Crashes

	Injuries Represented by 50th Percentile Male			Injuries Represented by 5th Percentile Female			Injuries Potentially Impacted by Improving Sensor Algorithm		
	Head	Neck	Chest	Head	Neck	Chest	Head	Neck	Chest
Drivers	44,503	1,648	31,317	8,893	387	8,119	7,947	306	5,807
Belted	25,409	941	17,881	5,077	221	4,636	4,537	175	3,316
Unbelted	19,094	707	13,436	3,816	166	3,483	3,410	131	2,491
Passengers	10,280	367	4,406	6,690	1,808	3,436	2,552	329	1,152
Belted	5,954	213	2,552	3,875	1,047	1,990	1,478	191	667
Unbelted	4,326	154	1,854	2,815	761	1,446	1,074	138	485
Total	54,783	2,015	35,723	15,583	2,195	11,555	10,499	635	6,959
Belted	31,363	1,154	20,433	8,952	1,268	6,626	6,015	366	3,983
Unbelted	23,420	861	15,290	6,631	927	4,929	4,484	269	2,976

Source: 1993-1997 CDS; 1997 GES.
Note: MAIS 2-5 injuries were derived from 1993-1997 CDS and adjusted to 1997 GES CDS equivalent level.

Table VI-32 shows the injury reduction benefits. An air bag passing the 30 mph rigid barrier test with unbelted 50th percentile males and meeting the ICPLs would reduce 6 to 16 MAIS 2-5 injuries. An air bag that passes the 30 mph, rigid barrier unbelted 5th percentile test would reduce 141 MAIS 2-5 injuries, while one passing the 30 mph rigid barrier, belted 5th percentile female test would reduce 43 MAIS 2-5 injuries. The 25 mph offset, belted 5th percentile female test would reduce 134-262 MAIS 2-5 injuries.

Table VI-32
MAIS 2-5 Injuries Reduced by Test Types for
Improved Occupant Protection From High Speed Crash Tests

		Head	Neck	Chest	Total
20 to 30 mph, Rigid Barrier, 0 and ± 30 Degree Unbelted 50th Percentile Male	**Drivers**	0 (0)	0	0	0* (0*)
	Passengers	16 (6)	0	0	16 (6)
	Total	16 (6)	0	0	16 (6)
Up to 30 mph, Rigid Barrier, 0 Degree Belted 50th Percentile Male	**Drivers**	0 (0)	0	0	0* (0*)
	Passengers	0 (0)	0	0	0* (0*)
	Total	0 (0)	0	0	0* (0*)
20 to 30 mph, Unbelted 5th Percentile Female**	**Drivers**	0 (0)	15	55	70 (70)
	Passengers	0 (0)	41	30	71 (71)
	Total	0 (0)	56	85	141 (141)
Up to 30 mph, Belted 5th Percentile Female	**Drivers**	0 (0)	16	12	28 (28)
	Passengers	0 (0)	8	6	14 (24)
	Total	0 (0)	24	18	42 (42)
Up to 25 mph, Offset, Belted 5th Percentile Female	**Drivers**	0 (0)	36	0	36 (36)
	Passengers	215 (87)	11	0	226 (98)
	Total	215 (87)	47	0	262 (134)

* No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
** Results were based on unrestrained tests and those failed the restrained tests.
Note: Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.

2.1 Injury Impact of Rigid Barrier 25 mph Unbelted Tests

This section estimates the impacts of 25 mph unbelted tests on MAIS 2-5 injuries. Two approaches that are similar to those described in the parallel section under fatalities were examined. The first approach derived the effectiveness rates by delta v levels from adult (age 13 and older) MAIS 2-5 injuries in 1993-1998 CDS. Head, neck, and chest injuries were examined separately from upper extremity injuries. Table VI-33 shows that 1,345 MAIS head, neck, and chest injuries would be reduced if a fleet of vehicles equipped with air bags designed to the 25 mph unbelted standard. Note that this approach compares relative risk of occupants in air bag equipped vehicles to those in vehicles without air bags using non-frontal crashes as the control group. The head, neck, and chest injuries in high speed (30 mph and above) non-frontal crashes were very small (a total of 21 cases with air bags over 6 years). The small sample size resulted a large estimation error, and thus may affect the reliability of the effectiveness for delta v category 30 mph and above.

Table VI-33
Impact of the 25 mph Unbelted Test on MAIS 2-5 Head, Neck, and Chest Injuries
Approach 1

If All Vehicles Had Pre-MY 1998 Air Bags (Passing the 30 mph, Rigid Barrier Test with Unbelted 50th Percentile Males)				**If All Vehicles Had New Designed Air Bags (Passing the 25 mph, Rigid Barrier Test with Unbelted 50th Percentile Males)**				
Delta V	Effective-ness	Target* Population	Injuries Reduced	Delta V	Effective-ness	Target* Population	Injuries Reduced	Benefits/ Disbenefits
0-20	0.016	34,520	552	0-15	0.016	22,142	354	
21-25	0.184	14,492	2,667	16-20	0.184	12,378	2,278	
26-30	0.116	7,588	880	21-25	0.116	14,492	1,681	
31+	0.149	5,598	834	26+	0.149	13,186	1,965	
Total		62,198	**4,933**	Total		62,198	**6,278**	**1,345**

Data Source: 1993-1998 CDS, 1997 FARS

* Unrestrained front-outboard adult MAIS 2-5 head, neck, and chest injuries based on 1993-1998 CDS.

Most of the upper extremity injuries were MAIS 2 or 3. These injuries occurred in the lower delta v impacts. Therefore, it is even more problematic using this approach to derive air bag effectiveness rates against upper extremity injuries by delta v levels. Instead, the analysis estimates upper extremity injury benefits/disbenefits by MAIS levels. Based on 1993-1998 CDS data, air bags caused 2,570 more AIS 2 upper extremity injuries, but reduced 625 AIS 3 upper extremity injuries. An air bag would deploy with less power if it were designed to the 25 mph unbelted tests, and thus would have the potential to reduce some of the 1,945 upper extremity MAIS 2 injuries. Due to lack of test data, the analysis can not quantify the benefits.

The second approach uses FMVSS 208 test data. Based on the FMVSS 208 tests, MY 1998 air bags have slightly higher HIC and chest g's. Thus, air bags only designed to the 25 mph unbelted tests would lose benefits in the high speed crashes. The analysis estimates that about 504 to 1,215 MAIS 2-5 adult injuries in 26+ mph impacts that were prevented by pre-MY 1998 air bags would not be reduced by the new redesigned air bags. The majority of these were MAIS 3+ injuries. On the other hand, the new redesigned air bags which deployed with a lesser power could reduce MAIS 2-5 injuries in the lower speed crashes as estimated in approach 1.

Judging from both crash tests and real-world crash data, the agency theorizes that single-stage air bags designed to maximize the 25 mph tests would lose benefits in higher speed crashes but gain benefits in lower speed crashes. Figure VI-1 uses the risk probabilities to illustrate the theorized concept. Because the vast majority of MAIS 2-5 injuries (especially MAIS 2 injuries) occur in the lower speed crashes, the benefits accrued from the low speed crashes might outnumber the disbenefits from high speed crashes (see approach 1). However, if the new designed air bags have a much smaller effectiveness against MAIS 2 injuries than against MAIS 3-5 injuries, the potential benefits from low speed crashes might be much smaller. Due to lack of low speed crash test data and statistically significant effectiveness rates of air bags against various injury levels, this approach can not reasonably estimate the total MAIS 2-5 injury benefits/disbenefits of new redesigned air bags.

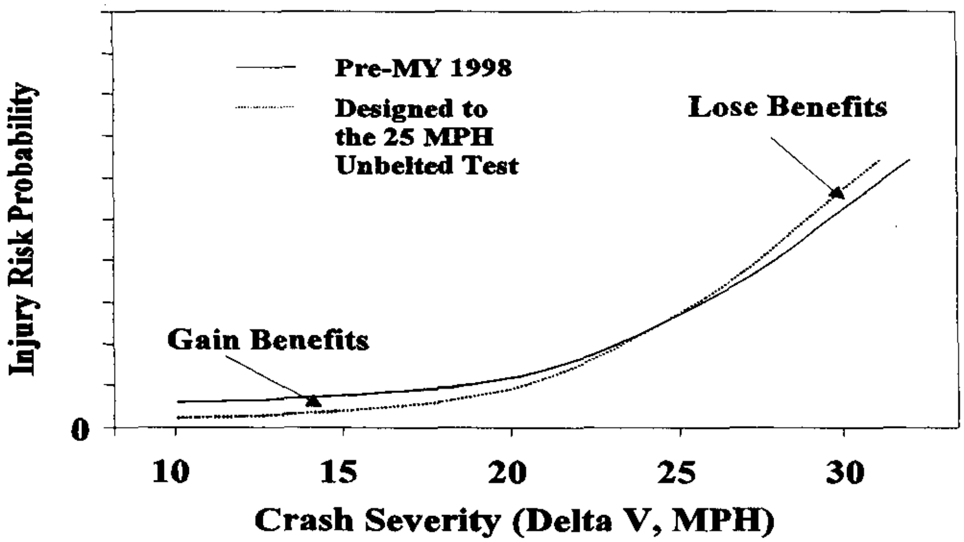

Figure VI-1. Theorized Concept of Risk Probability
Pre-MY 1998 vs Air Bags Designed to 25 MPH Unbelted Tests

The ideal dual-stage air bags would gain the benefits of having lower powered air bags at lower crash severity and at the same time not lose the benefits at higher crash severity. Multi-stage air bags would provide the same level of benefits during the first stage, whether the second stage is designed for a 25 mph unbelted test or for a 30 mph unbelted test, because they are both assumed to pass the low risk deployment tests with the first stage of deployment. As shown in Figure VI-1 and Table VI-33, multi-stage inflators gain injury benefits in the lower severity crashes. Note that the injuries prevented reflects the gain from low severity crashes as well as lost injury benefits from high speed crashes. If the second stage inflator were maintained at current levels, the lost benefits at higher impact speed would be eliminated. This would increase the injuries prevented. Since the lost and gained injury benefits couldn't be quantified separately in the analysis, the estimated net injury benefits will be reported for the first-stage of the multi-stage inflators, regardless of the high speed unbelted test requirements for the second stage. This is a conservative estimate.

2.1 Injury Impact of Rigid Barrier 35 mph Belted Tests

This section discusses the MAIS 2-5 injury impacts of the 35 mph rigid barrier perpendicular belted tests. The approach measures the pre-MY 1998 NCAP test data against injury criteria. The theory and procedures to derived the benefits were described in the methodology section (Section B). The 35 mph belted tests with 50th percentile males would reduce an estimated 256 to 486 MAIS 2-5 injuries. The same tests with 5th percentile females (not considered for this rulemaking) would reduce an estimated 143 to 205 injuries.

3. Summary of Benefits From High Speed Crashes

Estimates of the relative impact of the unbelted high speed tests are subject to a degree of uncertainty, since no vehicles were ever designed to meet a 25 mph unbelted test. We cannot estimate the most likely difference between setting the unbelted tests at the two different levels, because it depends on how the manufacturers would meet the alternative performance requirements. NHTSA believes that it is unlikely that vehicle manufacturers will significantly depower their air bags compared to the MY 1998-2000 fleet. If the manufacturers keep the same level of power as they currently have in MY 1998-2000, even with a 25 mph unbelted test requirement, then the difference in actual benefits between the two test speeds would be small or even eliminated. To set a high end of the range of benefits it is assumed that there would be no difference in benefits between vehicles designed to a 25 mph unbelted standard and vehicles designed to a 30 mph unbelted standard. It is likely that the future answer will not be at the bounds of the range, but within the bounds of the range.

At the same time, we cannot rule out the possibility that air bags will be significantly depowered. To account for this possibility, we calculated a "worst case" scenario comparing the benefits at the minimum performance requirements of each speed. We derived point estimates using two different methods and different sets of assumptions. We estimate that vehicles designed with 30 mph air bags could provide 229 or 394 more lives saved than vehicles designed with minimally compliant 25 mph air bags. These point estimates do not necessarily define the full range of possible outcomes due to uncertainty regarding both data and assumptions.

The less aggressive air bags that can be designed to a 25 mph unbelted test can result in fewer air bag caused injuries at low speeds than an air bag designed to a 30 mph unbelted test. Thus, air bags designed to a 30 mph unbelted test can prevent more fatalities, while single-stage air bags designed to a 25 mph unbelted test can prevent more injuries.

Table VI-34 summarizes the improved fatality and MAIS 2-5 injury benefits/disbenefits from high speed crash tests. Benefits are additive because this analysis assumes (1) 25-mph offset crashes would improve sensor technology and thus impact those out-of-position occupants. (2) The high speed rigid barrier tests would benefit those properly positioned occupants. And (3) the MAIS 2-5 injury benefits for 25-mph rigid barrier tests were from lower crash severity (in this methodology, there was a loss of benefits at higher speeds and a gain in benefits at lower speeds), while the benefits from the 30-mph rigid barrier tests were from higher crash severity (taking dummy measurements in crash tests down to the ICPLs). These two benefits are mutually exclusive, thus they are additive.

Based on the additive principle, 370 lives fewer lives to 32 more lives would be saved by a fleet of vehicles with air bags passing Alternative #1. These air bags would reduce 1,522 to 1,650 MAIS 2-5 injuries. Air bags passing Alternative #2 would save 43 to 51 lives, additional to the 3,253 lives saved by pre-MY 1998 models. These air bags would reduce 324 to 1,807 MAIS 2-5 injuries. A fleet of air bags passing Alternative #3, 370 fewer lives to 36 more lives would be saved. These air bags passing Alternative #3 would reduce 1,778 to 2,136 MAIS 2-5 injuries. The high end of benefits comes from the multi-stage inflators.

Table VI-34
Summary of Fatality and MAIS 2-5 Injury Benefits
from High Speed Crash Tests*

High Speed Tests	Fatalities			MAIS 2-5 Injuries		
	Drivers	Passengers	Total	Drivers	Passengers	Total
20 to 30 mph Rigid Barrier, 0 and ±30 Degree Unbelted 50th Percentile Male	0	0	0**	0	6-16	6-16
Up to 30 mph Rigid Barrier, 0 Degree Belted 50th Percentile Male	0	0	0**	0	0	0**
20 to 30 mph Rigid Barrier, 0 Degree Unbelted 5th Percentile Female	9	10	19	70	71	141
Up to 30 mph Rigid Barrier, 0 Degree Belted 5th Percentile Female	4	0	4	29	14	43
25 mph Offset, Belted 5th Percentile Female	18	2-10	20-28	36	98-226	134-262
25 mph Unbelted 50th Male and 5th Female	-309 to 0	-85 to 0	-394 to 0	1,036	309	1,345
Up to 35 mph Rigid Barrier, 0 Degree Belted 50th Percentile Male	0-3	0-1	0-4	213-392	43-94	256-486

* All of these test types are additive.
** No additional benefits beyond those already achieved from Pre-MY 1998 air bags.

Most of the difference between Alternatives #1 and #3, and Alternative #2 is due to the high-speed unbelted test. The 30 mph unbelted test will provide more protection against fatalities in high speed crashes. A single-stage air bag designed to meet a 30 mph test would save from 19 to 413 more lives than one designed to a 25 mph standard. However, the 25 mph test could result in single-stage air bag designs that would reduce about 1,200 more nonfatal injuries than the 30 mph test. The difference between Alternative #1 and Alternative #3 is small (0-4 lives). The small difference is due to the 5 mph increase in test speed to 35 mph for restrained 50th percentile males. See also Figure VI-2 which illustrates the process to derive the fatality benefits.

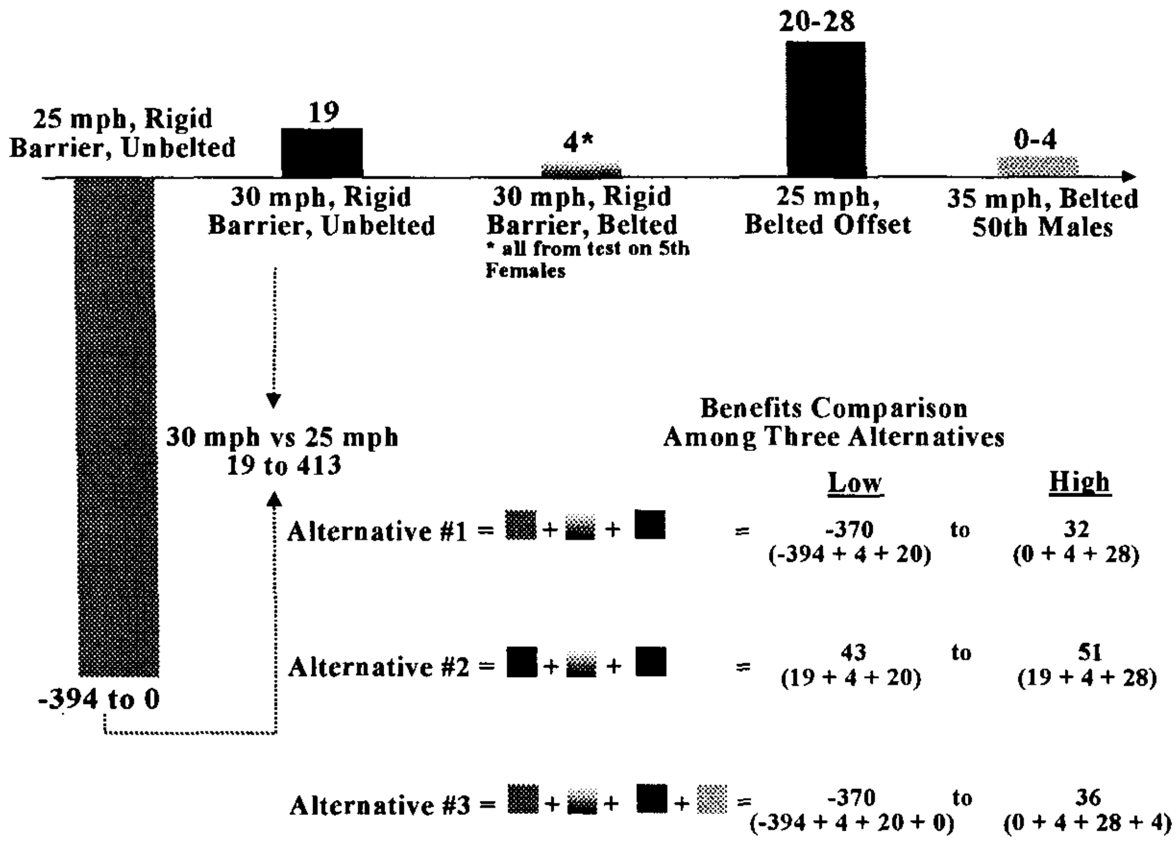

Figure VI-2 Benefits From High Speed Crashes

D. Benefits Summary

This section provides several tables to summarize the fatality/injury benefits/disbenefits discussed above. These benefits included both at-risk groups and improved protection. Tables VI-35 and VI-36 provide estimated fatality and injury benefits for the alternative tests. Benefits for those tests that impacted the at-risk groups were not mutually exclusive, and thus, not all benefits of these test types are additive.

Table VI-35
Estimated Incremental Lives Saved Annually by Test Type
Compared to Pre-MY 1998 Air Bag Systems*

Tests	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
Suppression When Presence	0(1)	18	75	0(1)	93
Suppression When Out-of-Position	46	0(1)	105	18	169
Low Risk Deployment	24	17-18	95-96	16	152-154
20 to 30 mph, 0 and ± 30 Degree Unbelted 50th Percentile Male	0(2)	0(1)	0(1)	0(2)	0(2)
Up to 30 mph, 0 and ± 30 Degree Belted 50th Percentile Male	0(2)	0(1)	0(1)	0(2)	0(2)
20 to 30 mph, 0 Degree Unbelted 5th Percentile Female	9	0(1)	0(1)	10	19
Up to 30 mph, 0 Degree Belted 5th Percentile Female	4	0(1)	0(1)	0(2)	4
Up to 25 mph Offset, Belted 5th Percentile Female	36	0(1)	0(1)	4-12	40-48
25 mph Rigid Barrier, Unbelted 50th Percentile Male and 5th Female	-278 to 0	0(1)	0(1)	-72 to 0	-350 to 0
Up to 35 mph, 0 Degree, Belted 50th Percentile Male	0-3	0(1)	0(1)	0-1	0-4

* Not all of these test types are additive, see Tables VI-37, VI-39, and VI-41.
1 Not proposed test for this group.
2 No additional benefits beyond those already achieved from Pre-MY 1998 air bags.

Table VI-36
Estimated Incremental MAIS 2-5 Injuries Reduced Annually by Test Type
Compared to Pre-MY 1998 Air Bag Systems*

Tests	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
Suppression When Presence	0(1)	9	142	0(1)	151
Suppression When Out-of-Position	38	0(1)	200	15	253
Low Risk Deployment	20	5	154	11	191
20 to 30 mph, 0 and ± 30 Degree Unbelted 50th Percentile Male	0(2)	0(1)	0(1)	6-16	6-16
Up to 30 mph, 0 and ± 30 Degree Belted 50th Percentile Male	0(2)	0(1)	0(1)	0(2)	0(2)
20 to 30 mph, 0 Degree Unbelted 5th Percentile Female	70	0(1)	0(1)	71	141
Up to 30 mph, 0 Degree Belted 5th Percentile Female	29	0(1)	0(1)	14	43
Up to 25 mph Offset, Belted 5th Percentile Female	54	0(1)	0(1)	101-229	155-283
25 mph Rigid Barrier, Unbelted 50th Percentile Male and 5th Female	1,062	0(1)	0(1)	320	1,382
Up to 35 mph, 0 Degree, Belted 50th Percentile Male	213-392	0(1)	0(1)	43-94	256-486

* Not all of these test types are additive, see Tables VI-38, VI-40, and VI-42.
1 Not proposed test for this group.
2 No additional benefits beyond those already achieved from Pre-MY 1998 air bags.

The following tables show estimated benefits for the air bag systems: a generic system without multi-stage inflation, the multi-stage inflation system, and the multi-stage inflation system with a 54 pound weight suppression option. The generic system was assumed to suppress the passenger side air bag by passenger's weight (<=54 pounds). Tables VI-37 and VI-38 show the benefits for air bag systems passing a combination of suppression, low risk deployment, and Alternative #1 of the high speed crash tests. Tables VI-39 and VI-40 list the benefits for air bag systems passing Alternative #2 of the high speed crashes. Tables VI-41 and VI-42 list the benefits for air bag systems passing Alternative #3 of the high speed crashes. Note that the generic system might not pass the low risk deployment for children and adults. Also note that the first stage of the multi-stage inflation system is assumed to pass the low risk deployment for infants, children, and adults. Air bags passing the low risk deployment tests for children and adults would be more benign than those passing the 25-mph rigid barrier tests. Therefore, all the injury benefits accrued from 25-mph rigid barrier tests were included in the multi-stage inflation system.

As shown in Tables VI-37 and VI-38, for air bags passing a combination of suppression, low-risk deployment, and Alternative #1 of the high speed crash tests, 233 fewer lives to 211 more lives would be saved. These air bags would reduce 1,710 to 1,902 MAIS 2-5 injuries. Air bags, as shown in Table VI-39 and VI-40, would save 156-230 lives and reduce 496 to 2,059 MAIS 2-5 injuries if the air bags passed a combination of suppression, low-risk deployment, and Alternative #2 of the high speed crash tests. As shown in Tables VI-41 and VI-42, for air bags passing a combination of suppression, low-risk deployment, and Alternative #3 of the high speed crash tests, 233 fewer lives to 215 more lives would be saved. These air bags would reduce 1,966 to 2,388 MAIS 2-5 injuries. The multi-stage inflation system with a 54-pound weight sensor would reap the highest benefits in both cases.

Table VI-37
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #1 of the High Speed Crash Tests

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	-256 to 40	18	75	-70 to 12	-233 to 145
Multi-Stage Inflation System Based on Crash Severity and Belt Use	-247 to 62	18	102	-66 to 27	-193 to 209
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	-247 to 62	18	104	-66 to 27	-191 to 211

* Air bag might not pass the low risk deployment for children and adults.

Table VI-38
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #1 of the High Speed Crash Tests

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	1,127	9	142	432-560	1,710-1,838
Multi-Stage Inflation System Based on Crash Severity and Belt Use	1,134	8	187	434-562	1,763-1,891
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	1,134	9	197	434-562	1,774-1,902

* Air bag might not pass the low risk deployment for children and adults.

Table VI-39
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #2 of the High Speed Crash Tests

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	49	18	75	14-22	156-164
Multi-Stage Inflation System Based on Crash Severity and Belt Use	71	18	102	29-37	220-228
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	71	18	104	29-37	222-230

* Air bag might not pass the low risk deployment for children and adults.

Table VI-40
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #2 of the High Speed Crash Tests

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	153	9	142	192-330	496-634
Multi-Stage Inflation System Based on Crash Severity and Belt Use	1,204	8	187	511-649	1,910-2,048
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	1,204	9	197	511-649	1,921-2,059

* Air bag might not pass the low risk deployment for children and adults.

Table VI-41
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #3 of the High Speed Crash Tests

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	-256 to 43	18	75	-70 to 13	-233 to 149
Multi-Stage Inflation System Based on Crash Severity and Belt Use	-247 to 65	18	102	-66 to 28	-193 to 213
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	-247 to 65	18	104	-66 to 28	-191 to 215

* Air bag might not pass the low risk deployment for children and adults.

Table VI-42
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #3 of the High Speed Crash Tests

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	1,340-1,519	9	142	475-654	1,966-2,324
Multi-Stage Inflation System Based on Crash Severity and Belt Use	1,347-1526	8	187	477-656	2,019-2,377
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	1,347-1,526	9	197	477-656	2,030-2,388

* Air bag might not pass the low risk deployment for children and adults.

E . Sensitivity Study #1, Safety Belt Use

This section estimates the change in benefits that could result from increased safety belt use. Based on state surveys, in 1997, the average national belt usage rate was 66.9 (base year usage rate) percent. The analysis examines air bag benefits at a increased observed belt usage rate of 85.0 percent (85 percent is the DOT goal for 2000), which corresponds to an 18 percentage point increase over the base rate[8].

To estimate the benefits of advanced air bags at the 85.0 percent belt use rate, the analysis needed to adjust the baseline target population to reflect the impact of increased belt use. Then, the procedure was applied as stated in previous sections, to derive the new benefit of advanced air bags. NHTSA's belt usage software (BELTUSE) program[9] (Blincoe, 1994) was used to derive the incremental benefits. The target population for at-risk and improved occupant protection were input to the program to calculate the incremental safety benefits. The BELTUSE program estimated that 8 fatalities and 9 MAIS 3-5 injuries for at-risk groups and 1,504 adult fatalities and 16,467 adult MAIS 2-5 injuries for improved protection would be saved or prevented by increasing belt use from the base 66.9 percent to 85.0 percent. The difference between the baseline population and the incremental safety belt impacts is the adjusted baseline population.

[8] The method assumes observed belt use increases to 85 percent, changing the target population for air bags. Under these assumptions, air bags would save 1,072 belted and 1,639 unbelted lives for a total of 2,711 lives with a full fleet of air bags, compared to the 3,253 lives (see Table II-3) at 66.9 percent belt use.

[9] PC-DOS based software. The program also can be ran under the Microsoft Window environment.

The benefits of advanced air bags at 85 percent belt use were derived by applying those reduction rates/percentages (Table VI-4-A to VI-5-B) to the adjusted population. Tables VI-43 to VI-50 summarizes the estimated benefits for alternative tests and air bag systems at the 85.0 percent belt use rate.

As shown in Tables VI-45 and VI-46, for air bags passing a combination of suppression, low-risk deployment, and Alternative #1 of the high speed crash tests, 115 fewer lives to 205 more lives would be saved. The same air bags would reduce 1,276 to 1,460 MAIS 2-5 injuries. Air bags, as shown in Table VI-47 and VI-48, would save 148-219 lives and reduce 446 to 1,570 MAIS 2-5 injuries if it passed combination of suppression, low-risk deployment, and Alternative #2 of the high speed crash tests. As shown in Tables VI-49 and VI-50, for air bags passing a combination of suppression, low-risk deployment, and Alternative #3 of the high speed crash tests, 115 fewer lives to 211 more lives would be saved. The same air bags would reduce 1,522 to 1,999 MAIS 2-5 injuries.

Table VI-43
Estimated Incremental Lives Saved Annually by Test Type
Compared to Pre-MY 1998 Air Bag Systems*
at 85.0 Percent Belt Use Rate

Tests	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
Suppression When Presence	0(1)	18	75	0(1)	93
Suppression When Out-of-Position	42	0(1)	103	16	161
Low Risk Deployment	22	17-18	93-94	14-15	146-149
20 to 30 mph, 0 and ± 30 Degree Unbelted 50th Percentile Male	0(2)	0(1)	0(1)	0(2)	0(2)
Up to 30 mph, 0 and ± 30 Degree Belted 50th Percentile Male	0(2)	0(1)	0(1)	0(2)	0(2)
20 to 30 mph, 0 Degree Unbelted 5th Percentile Female	6	0(1)	0(1)	8	14
Up to 30 mph, 0 Degree Belted 5th Percentile Female	5	0(1)	0(1)	0(2)	5
Up to 25 mph Offset, Belted 5th Percentile Female	32	0(1)	0(1)	4-12	36-44
25 mph Rigid Barrier, Unbelted 50th Percentile Male and 5th Female	-188 to 0	0(1)	0(1)	-43 to 0	-231 to 0
Up to 35 mph, 0 Degree, Belted 50th Percentile Male	0-4	0(1)	0(1)	0-2	0-6

* Not all of these test types are additive, see Tables VI-45, VI-47, and VI-49.
1 Not proposed test for this group.
2 No additional benefits beyond those already achieved from Pre-MY 1998 air bags.

Table VI-44
Estimated Incremental MAIS 2-5 Injuries Reduced Annually by Test Type
Compared to Pre-MY 1998 Air Bag Systems*
at 85.0 Percent Belt Use Rate

Tests	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
Suppression When Presence	0(1)	9	142	0(1)	151
Suppression When Out-of-Position	34	0(1)	196	14	244
Low Risk Deployment	18	5	151	11	185
20 to 30 mph, 0 and ± 30 Degree Unbelted 50th Percentile Male	0(2)	0(1)	0(1)	4-11	4-11
Up to 30 mph, 0 and ± 30 Degree Belted 50th Percentile Male	0(2)	0(1)	0(1)	0(2)	0(2)
20 to 30 mph, 0 Degree Unbelted 5th Percentile Female	49	0(1)	0(1)	50	99
Up to 30 mph, 0 Degree Belted 5th Percentile Female	32	0(1)	0(1)	15	47
Up to 25 mph Offset, Belted 5th Percentile Female	50	0(1)	0(1)	95-215	145-265
25 mph Rigid Barrier, Unbelted 50th Percentile Male and 5th Female	731	0(1)	0(1)	221	952
Up to 35 mph, 0 Degree, Belted 50th Percentile Male	199-436	0(1)	0(1)	47-103	246-539

* Not all of these test types are additive, see Tables VI-46, VI-48, and VI-50.
1 Not proposed test for this group.
2 No additional benefits beyond those already achieved from Pre-MY 1998 air bags.

Table VI-45
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #1 of the High Speed Crash Tests
at 85.0 Percent Belt Use Rate

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	-167 to 37	18	75	-41 to 12	-115 to 142
Multi-Stage Inflation System Based on Crash Severity and Belt Use	-158 to 58	18	102	-38 to 25	-76 to 203
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	-158 to 58	18	104	-38 to 25	-74 to 205

* Air bag might not pass the low risk deployment for children and adults.

Table VI-46
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #1 of the High Speed Crash Tests
at 85.0 Percent Belt Use Rate

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	797	9	142	328-448	1,276-1,396
Multi-Stage Inflation System Based on Crash Severity and Belt Use	804	8	187	330-450	1,329-1,449
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	804	9	197	330-450	1,340-1,460

* Air bag might not pass the low risk deployment for children and adults.

Table VI-47
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #2 of the High Speed Crash Tests
at 85.0 Percent Belt Use Rate

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	43	18	75	12-20	148-156
Multi-Stage Inflation System Based on Crash Severity and Belt Use	64	18	102	25-33	209-217
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	64	18	104	25-33	211-219

* Air bag might not pass the low risk deployment for children and adults.

Table VI-48
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #2 of the High Speed Crash Tests
at 85.0 Percent Belt Use Rate

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	131	9	142	164-291	446-573
Multi-Stage Inflation System Based on Crash Severity and Belt Use	853	8	187	384-511	1,432-1,559
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	853	9	197	384-511	1,443-1,570

* Air bag might not pass the low risk deployment for children and adults.

Table VI-49
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #3 of the High Speed Crash Tests
at 85.0 Percent Belt Use Rate

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	-167 to 41	18	75	-41 to 14	-115 to 148
Multi-Stage Inflation System Based on Crash Severity and Belt Use	-158 to 62	18	102	-38 to 27	-76 to 209
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	-158 to 62	18	104	-38 to 27	-74 to 211

* Air bag might not pass the low risk deployment for children and adults.

Table VI-50
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #3 of the High Speed Crash Tests
at 85.0 Percent Belt Use Rate

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation with a 54-Pound Weight Sensor*	996-1,233	9	142	375-551	1,522-1,935
Multi-Stage Inflation System Based on Crash Severity and Belt Use	1,003-1,240	8	187	377-553	1,575-1,988
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	1,003-1,240	9	197	377-553	1,586-1,999

* Air bag might not pass the low risk deployment for children and adults.

F. Sensitivity Analysis #2, Redesigned Air Bags

As shown in Table II-5, based on the minimal amount of data available for MY 1998 redesigned air bags, the estimated 187 at-risk fatalities with pre-MY 1998 air bags could be estimated to be about 65 fatalities with redesigned air bags.

Table VI-6 showed that all 18 infants in RFCSS in the target population for pre-MY 1998 air bags could be saved with suppression, low risk or multi-stage inflator systems. Similarly, all 10 infants in RFCSS in the target population for redesigned air bags could be saved.

Suppression by 54-pound weight limit would save 75 children out of the total target population for pre-MY 1998 air bags of 105. As shown in Tables VI-7 to VI-10, the advanced air bags passing the low risk tests or with the multi-stage inflation would save somewhere between 94 and 104 children 1-12 years old lives. The suppression by weight air bag systems would save 25 children if measured by the redesigned target population of 35 fatalities. While the advanced air bags passing the low risk tests or with the multi-stage inflation would save 31 to 35 children.

For drivers, low risk deployment could save 24 fatalities in the target population for pre-MY 1998 air bags. Table VI-12 shows that an estimated 40 of 46 out-of-position driver fatalities could be reduced by multi-stage inflators. Based on the target population of and test results from redesigned air bags, the low risk deployment could save 8 fatalities (52.23 percent of the target population); and the multi-stage inflators could save about 13 lives.

As for the suppression systems, one potential concern in disabling the right front passenger air bag when no one or a low weight person is in the right front seat is in not having an air bag for an unbelted driver who could slide to the right and strike the right instrument panel or right side A-pillar. There are a small number of cases without air bags in the NASS files where a crash at 2 or 3 o'clock resulted in an unbelted driver being thrown across the vehicle to the right front side, where the driver sustained injuries. Potentially an air bag could provide benefits in this situation. The agency does not know of a case where an air bag has actually provided a benefit in this type of crash, but it is theoretically possible. Therefore, there could be some small loss in safety for unbelted drivers by suppressing the right front passenger air bag.

The benefit estimates are based on the assumptions that all vehicles in the on-road fleet are equipped with air bags and there are no changes in occupant demographics, driver/passenger behavior, belt use, child restraint use, or the percent of children sitting in the front seat. Behavior modification or changes through public education and safety awareness campaigns could have a positive impact on occupant safety and thus affect the potential benefits of advanced air bags. One such change is increasing safety belt usage. As shown in the sensitive study, at 85 percent belt use rate, the benefits of the advanced air bags would less, yet still a great number of fatalities and injuries can be saved or prevented.

In addition, if more children ride in the back seat, fewer children would be killed by air bags. The statistics cited in Table II-9 indicates this trend. The child fatalities that advanced air bags are intended to eliminate would thus be smaller in number. However, if labels and education result in more children sitting in the rear seat, the agency is concerned that this rulemaking to decrease the threat of injury from air bags in the front seat could result in the belief by many members of the public that the front seat is now safe for children, and more children would then sit in the front seat. The fatality rate is 22 percent lower in the rear seat than the front seat for all occupants and 27 percent lower for children up through age 12. Since air bags are about 11 percent effective overall for occupants over 12 years old, the safety of all occupants (adults and children) is enhanced by sitting in the rear seat. Education efforts will continue to try to keep children in the rear seat.

Another change might be that short or older drivers would be willing to make seating adjustments so that they are as far away from the steering wheel as possible and still feel comfortable while driving. Ford is already providing adjustable pedals on some high volume cars to assist drivers in moving further away from the steering column. This could also reduce the number of air bag induced fatalities and the corresponding potential benefits of advanced air bag systems.

VII. TECHNOLOGY COSTS, AND LEADTIME

There are a variety of technologies that could be used by the vehicle manufacturers to meet the final rule. In this chapter we discuss the cost of the different technologies that are in development that could be used to comply with the tests, determine current compliance with the tests, property damage savings from using different technologies, and estimate the compliance test costs. Leadtime is the last section of this chapter.

A. Technology Costs

There were no comments to the SNPRM docket (6407) regarding costs for specific technologies. Comments relating to costs mainly state that there are too many compliance tests.

Several cost estimates come from NHTSA contractor tear-down studies of costs[1]. Some of the cost estimates come from comments to the docket from 1996 (Docket 74-14-N100). Numbers in parentheses ( ) behind a manufacturer's name indicate their comments to this docket and the comment number. Other cost estimates come from the Jet Propulsion Lab (JPL)[2] analysis and

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[1] "Report/Comparison Multi-stage Air bag Inflator vs. Single Stage Air bag Inflator", Ludtke & Associates, Docket No. 98-4405 No.3.

"Cost, Weight, and Lead Time Analysis: Tear Down Analysis of Two Existing Air Bag Systems", Bruce C. Spinney, NHTSA, September 1998, Docket No. 98-4405 No. 4.

"Final Report Volume I of Cost, Weight, and Lead Time Analysis: Tear Down Analysis of Two Existing Air Bag Systems" Ludtke & Associates, Docket No. 98-4405 No. 5.

"Final Report Volume II of Cost, Weight, and Lead Time Analysis: Tear Down Analysis of Two Existing Air Bag Systems" Ludtke & Associates, Docket No. 98-4405 No. 6.

[2] "Advanced Air Bag Technology Assessment", Jet Propulsion Lab, April 1998.

review of advanced air bag technologies (Docket No. NHTSA-1997-2814). Finally, a few cost estimates come from confidential responses from an Information Request sent to air bag suppliers.

The agency believes that the 50^{th} percentile male dummy restrained 30 mph barrier test, unrestrained 25 mph barrier test, and unrestrained 30 mph barrier tests can probably be met by the manufacturers without any incremental costs compared to today's air bags. The design challenges for the manufacturers are in meeting these barrier tests while at the same time trying to reduce the potential problems for out-of-position occupants. Similarly, the agency believes that the 5^{th} percentile female dummy restrained at 30 mph and unrestrained at 25 mph can probably be met by the manufacturers without any incremental costs compared to today's air bags. However, the agency believes that in order to meet the 30 mph unbelted barrier test using the 5^{th} percentile female dummy, multi-stage inflators may be necessary. The assumptions in this cost analysis are that adding the out-of-position tests, offset frontal test, and the 5^{th} percentile female dummy in the unbelted 30 mph test will require some manufacturers to make changes in their restraint systems or vehicle structure.

1. Suppression of the Air Bag

The principal costs for a suppression system are in the sensing systems and algorithm development. Sensing systems are designed to provide information to be used in the air bag computer logic (algorithms) to determine when to suppress the air bag, or which level of air bag deployment is the best for the combination of occupant size, occupant position, restraint use, and crash type. The agency estimates the internal components to suppress the air bag (just the part of the internal air bag circuitry to be able to turn the air bag off) costs less than $1 per air bag.

The agency is requiring two telltale lights to show when the air bag is turned off, one for the driver side and one for the passenger side air bag. The agency contracted with Troy Design Services to estimate the cost of the passenger-side air bag on/off switch. The estimated cost for the warning light LED, wiring, bezel; and two wire clips were estimated to be $1.49. The addition of a second LED for the driver would add about $0.11 for a total cost of $1.60 (1997 dollars). For this analysis, the cost is delegated to $0.80 for each side (driver and passenger).

2. Low Risk Deployment

The cost of meeting the final rule using the low risk deployment depends on the technology option chosen. For the driver side, it is possible that it could be a no cost option, just a different design of the air bag. In general, the agency believes changes in fold patterns, tethering, or venting can probably be done at no incremental cost. Morton (075) stated that an air bag that utilizes different fold patterns and inflators may add very little incremental costs to the current air bag systems.

The agency does not believe it is likely that a no-cost low risk deployment air bag will be forthcoming in the near future for the passenger side, and assumes that at least a multi-stage inflator will be necessary for the passenger side.

The need for and costs of potentially adding padding or other countermeasures to go along with the low risk deployment option is unknown. No commenter suggested this was necessary.

3. Crash Severity Sensors

Tear-down data from three 1992 models (Ford Crown Victoria, Toyota Camry, and Plymouth Acclaim)[3] from NHTSA contractors estimate the average cost of adding two additional sensors at $22.30 (1997 dollars) and 1.36 pounds. The range of costs among the three vehicles was fairly close at $20.80 to $23.90.

4. Occupant Weight and Pattern Recognition

Several estimates of costs for weight sensors are available:

A teardown study of the Mercedes-Benz seat switch pad by a NHTSA contractor resulted in the cost estimate of $19.45 (1997 dollars)[4] and 3.7 ounces per seat position. It is anticipated that the

[3] Ford/Crown Victoria - DOT HS 807 949, September 1992
"Cost Estimates of Manual & Automatic Crash Protection Systems in Selected 1988-1992 Model Year Passenger Cars" Volume I

Toyota Camry and Tercel - DOT HS 807 950, September 1992
"Cost Estimates of Manual & Automatic Crash Protection Systems in Selected 1988-1992 Model Year Passenger Cars" Volume II

Plymouth Acclaim - DOT HS 807 951, September 1992
"Cost Estimates of Manual & Automatic Crash Protection Systems in Selected 1988-1992 Model Year Passenger Cars" Volume III

[4] "Cost, Weight, and Leadtime Impacts of a Mercedes-Benz "Sensormat" Type Occupant Detection System", NHTSA, April 1997, DOT HS 808 587. This cost was for vehicles with a domestic control module. The Mercedes control module was more sophisticated to begin with and the cost increment for Mercedes was estimated to be $12.30.

seat switch pad would be useful only for the passenger side. Mercedes-Benz of North America (034) estimated the cost of their seat switch pad to be $17.33 (1997 dollars).

A second tear down study by a NHTSA contractor[5] of a MY 2000 BMW Z3, found a consumer cost of $18.83 (1997 dollars).

General Motors (030) estimated that a weight based system for the passenger side is in the range of $10 to $20 variable cost (1996 dollars), which means on a consumer cost basis, the cost would be roughly $15.40 to $30.80 (e.g., $10 multiplied by 1.01987 to bring it from 1996 dollars to 1997 dollars[6] and by 1.51[7] to go from variable cost to consumer cost).

NEC Technologies (052) estimated the per vehicle cost for the weight sensor was in the range of $35.70, but that these costs would be reduced through mass production.

Saab (067) said that a weight based system would cost $30.60 (1997 dollars),

Morton (075) estimated a weight sensor would cost $20.40 (1997 dollars).

The range of cost estimates are from $15.40 to $35.70. For this analysis, the estimates from

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[5] Cost, Weight and Lead Time Analysis, Advanced Air Bag Systems, Ludtke & Associates

[6] Based on the Gross Domestic Product Implicit Price Deflator.

[7] Estimate based on historical analysis of 10K reports from domestic vehicle manufacturers.

Mercedes and the NHTSA tear down of the Mercedes and BMW mat type system were used, \$17 to \$20. However, these systems did not include the pattern recognition technology now being developed. While this information can be collected with a similar mat-type system, there will be an additional cost to develop the algorithm for pattern recognition and introduce it into the system. The agency estimates the costs of a weight sensor with a pattern recognition system to be \$19 to \$23. The agency has no cost estimates for the system using strain gauges or load cells.

5. Occupant Presence, Proximity and Motion Sensor Costs

There are a wide variety of occupant presence, proximity and motion sensors. The final rule does not require dynamic motion sensors. Thus, some of these technologies are mentioned here and are not carried forward in the analysis. Occupant presence sensing, to help determine occupant size and placement is considered a technology that could be used to provide more information for air bag deployment decisions. The agency has cost estimates for some of them. General Motors (030) stated the variable cost of a proximity based system was in the range of \$25.50 to \$45.90 (1997 dollars) for the passenger side depending on the system requirements. On a consumer cost basis, the costs would be \$38.50 to \$69.30 for the passenger side.

Automotive Technologies International, Inc. (ATI) (020) has developed an occupant position sensor, the Ultrasonic, Nonimaging Pattern Recognition. ATI claimed that the occupant position sensor was expected to cost between \$35.70 and \$42.80 for the passenger side.

The JPL study estimated that a system using capacitive presence sensors will cost between \$25 and $75. JPL also estimated that a system using acoustic and infrared sensor technology costs $35 to $60 dollars. These costs are supplier costs to the original manufacturers and do not include installation. Thus, a consumer cost is likely to be $37.80 to $113.30 for capacitive presence sensors and $52.90 to $90.60 for acoustic and infrared sensor technology. These estimates are for the passenger side seating position only. Adding similar systems to the driver side would cost an additional 50 to 100 percent of the passenger side cost, at this time it does not appear that manufacturers are considering driver side suppression technology.

There are a variety of systems under consideration. There will be intense price competition in this market and the lower priced systems that are reliable will be the ones used in vehicles. The agency estimates initial consumer costs for a presence sensor to be near the low end of costs discussed above, in the range of $40 to $60 for the passenger side. These costs should decrease over time.

6. Safety Belt Use Sensors

The driver side already has a restraint-use sensor to activate the warning light and buzzer if the driver is not using the safety belt. Based on a teardown study of cost for the driver side of a Toyota Tercel, the estimated cost for a passenger side sensor is $2.00. Manufacturers are developing more reliable systems for belt use sensors, to move from a mechanical to a non-mechanical system (known as the Hall effect). These systems are estimated to cost $5.00 and could be applied to both driver and passenger side.

7. Seat Position Sensor

The agency does not have a teardown cost estimate for a seat-position sensor. It is assumed to cost about $5.00 per seating position.

8. Dual Stage or Multiple Level Inflators

In the PEA for the SNPRM (See Docket No. 1999-6407-2), the agency had cost estimates for three inflators based on a contractor's tear-down study of a Chrysler Cirrus/Dodge Stratus single stage pyrotechnic inflator, a BMW single stage pyrotechnic inflator, and a TRW dual stage hybrid air bag inflator. The same contractor has finished two additional hybrid air bag inflators, one on a MY 2000 Taurus and one on a MY 2000 BMW Z3. Table VII-1 presents the updated cost estimates for all of these systems.

Table VII-1
Consumer Cost Estimates - Inflator Costs
(1997 Dollars)

	Driver	**Passenger**	**Total**
Single Stage Chrysler Cirrus - pyrotechnic	$26.89	$33.91	$60.80
Dual Stage Taurus - hybrid	$18.16	22.64	$40.80
Single Stage BMW 528i - pyrotechnic	$19.81	$48.95	$68.76
Dual Stage BMW Z3 - hybrid	$20.93	$43.37	$64.30
Dual Stage TRW - hybrid	$25.14	$28.51	$53.65

There is quite a difference in cost between the different systems. At first look, one would think a reasonable comparison would be between the Chrysler and the Taurus. However, the Chrysler system used an expensive aluminum canister which significantly raised its costs. The best comparison is for the BMW systems, since you have the same manufacturer making decisions. However, several things are changing in these cost estimates, single stage versus dual-stage, pyrotechnic inflators versus hybrid inflators, and the fact that the Z3 is smaller and may take a smaller air bag on the passenger side. For the BMW systems, the driver side dual-stage hybrid inflator was $1.12 more expensive than the single stage pyrotechnic inflator, but on the passenger side, the dual-stage hybrid inflator was $5.58 less expensive. Based on two of the first few dual-stage inflators on the market, it appears that the industry is moving toward hybrid inflators.

Whether a manufacturer uses a pyrotechnic inflator or a hybrid air bag inflator is a choice made in the normal course of business. What is needed for this analysis is an estimate of the incremental cost of a dual stage pyrotechnic inflator compared to a single stage pyrotechnic inflator and the incremental cost of a dual stage hybrid inflator compared to a single stage hybrid inflator.

Based on information from our contractor, the agency estimates that the incremental cost for a dual stage pyrotechnic inflator over a single stage pyrotechnic inflator is about $10 per inflator, and incremental cost for a dual stage hybrid inflator over a single stage hybrid inflator is about $2 per inflator.

JPL estimated the costs of different inflators compared to a baseline single stage pyrotechnic inflator with sodium azide propellants. These costs were $10 to $15 for a dual-pyrotechnic inflator, $0 to $8 for a hybrid or heated gas inflator and potentially lower cost for a high pressure stored gas inflator.

Thus, inflator costs vary considerably depending on the technology chosen. If the manufacturers stay with the more widely known and used pyrotechnic technology, the agency estimates the cost increase of a dual-stage pyrotechnic inflator is $10 per side, or $20 per vehicle. If manufacturers determine they can switch to a hybrid or gas system, they could save money compared to the pyrotechnic inflators. However, a dual-stage hybrid system would cost about $2 more than a single-stage hybrid system per side, or $4 per vehicle.

9. Pretensioners

One of the tests considered is to require a 35 mph belted test for the 50th percentile male dummy. For those manufacturers that don't meet the test already, the agency assumes that pretensioners on the seat belt system would be the technology used by manufacturers. The agency has two tear down studies of pretensioners. The first is on a BMW 528i (see Docket No. 98-4405, No. 4) which is estimated to have a consumer cost of $16.45 per seat (consumer cost). The second tear down was on a MY 2000 Taurus (this study has not yet been released). The estimated cost of pretensioners in this system was $18.40 in 1997 dollars per seat (consumer cost). The cost for a 1995 Ford Mustang[8] seatbelt latch assembly without pretensioners was estimated to be $7.10. Thus, the range of incremental cost is between $9.35 ($16.45 - $7.10) and $11.30 ($18.40 - $7.01) per seat.

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[8] Fladmark, Gary L. and Khadilkar, Anil V., "Csot Estimates of (1) Side Impact Crash Protection of 1994/95 Vs. 1993/94 Model Year Passenger Cars, (2) Automatic Crash Protection of 1995 Model Year Pickup Trucks, Vans and Multipurpose Passenger Vehicles, and (3) Automatic Crash Protection of Two 1995 Model Year Passengers Cars." Contract No. DTNH22-95-C-06006, September 1996.

10. Crash Pulse Changes

When new models are designed, manufacturers may have the ability to soften the crash pulse and potentially make it easier to meet the high speed tests with less aggressive air bags. Increasing the crush zone in the front of the vehicle, changing the load paths, or changing the materials used in the structure can soften the crash pulse. Some manufacturers advertise these design features and similar-sized vehicles have different crash pulses. The cost and effectiveness of these strategies varies considerably depending upon the specific make/model.

One way to soften the crash pulse is to increase the front end length of the vehicle by about three inches. This countermeasure might be considered for those vehicles with stiff crash pulses, typically small cars and large light trucks. There are several decisions that must be made when considering increasing the front end length. Should the overall length of the vehicle be maintained, either by decreasing the trunk room, cargo space, interior room, or by changing the engine configuration to provide more room in front? These are major decisions that affect how the vehicle looks, its design, and its function. In an attempt to provide a cost estimate for this countermeasure, the agency took previous tear-down study data from Ford F-100 and F-150 pickups[9], and estimated the cost to extend the front of the model by three inches. Based on 1978 economics, adding three inches to the hood, fenders, and frame rails would add \$9.40 and 11.7 pounds. Using the GDP, implicit price deflator, in 1997 dollars the cost would be \$20.60. The

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[9] See "1980 and 1979 Ford F-150 Light Truck Weight and Material Analysis", Corporate-Tech Planning, March 1980, DOT HS 805-693, and
"Development of a Motor Vehicle Materials Historical, High Volume Industrial Processing Rates Cost Data Bank (Light Truck)", John Z. DeLorean Corporation, October 1978, DOT HS 805-161.

agency also considers secondary weight effects. Secondary vehicle weight refers to weight increases to other parts of the vehicle to compensate for the additional primary weight. These secondary weight increases could conceivably include increases in vehicle structure (to maintain load-carrying ability) or an increase in average engine size (to maintain acceleration capability). In this case, we would consider the increase in primary weight to the hood and fenders (6.9 pounds), as influencing secondary weights. Historically, the agency has used a secondary weight factor of 0.7 pounds of secondary weight for every pound of primary weight and a cost of $0.95 per pound of secondary weight. Thus, the total weight influence would be 16.5 pounds [11.7 + 0.7(6.9)] and the total cost would be $27.15 [$20.60 + 6.9($0.95)]. As discussed above, this is only one of many ways to change the crash pulse.

There are a variety of potential ways for the manufacturers to meet the alternative test requirements. The cost estimates of these systems vary considerably. Table VII-2 shows the range of cost estimates provided. NHTSA has more confidence in cost estimates that have been provided by contractor tear-down studies, although there is no guarantee that these technologies are the ones that will actually go in to production. For this analysis, the agency will use the tear-down study cost estimates where provided, and will use the range of estimates provided by docket commenters or JPL when tear-down studies are not available.

Estimated Vehicle Costs for Meeting Specific Tests and Current Compliance

Table VII-3 presents costs for meeting specific individual tests. Table VII-5 presents costs for meeting specific individual tests after taking into account current compliance rates and considering the high speed tests discussed below. The manufacturers must meet a combination of tests. In some cases, the same technology could be used to meet both out-of position tests and high speed tests.

Table VII-2
Technology Cost Summary
(1997 Dollars)

Technology	Range of Cost Estimates	Cost Estimates Used in this Analysis
Suppression of Air Bag -- Internal Circuitry Only	$1 per air bag	$2 per vehicle
Telltale light	$0.80 per side	$1.60 per vehicle
Low Risk Air Bags	none	$0 to minor Assumed only available for the driver side
Two additional sensors for the offset test	$20.80 to $23.90 per vehicle	$22.30 per vehicle
Weight or mass sensor with pattern recognition	$15.40 to $35.70 per seat	$19 to $23 per vehicle Assumes only passenger side
Occupant Presence Sensors	$35.70 to $113.30 for the passenger side	$40 to $60 for the passenger side
Safety Belt Use Sensor	$2.00 to $5.00 per vehicle	$2.00 to $5.00 per vehicle Only needed on passenger side
Dual or Multiple Level Inflators	$2 to $15 per air bag	$2 to $10 per side or $4 to $20 per vehicle
Crash Pulse Changes	$27.15 per vehicle	$27.15 per vehicle
Threshold Changes	none	$0 to unknown
Redesigned Air Bag	none	$0
Pretensioners	$9.35 to $11.30 per seat	$18.70 to $22.60 per vehicle

In this chapter, costs for specific tests are estimated. Chapter VIII combines out-of-position tests and high speed tests into four compliance scenarios and combines costs for specific tests looking at the potential low and high costs of meeting a full compliance scenario.

The assumptions for Tables VII-3 and VII-5 are:

1. To meet the suppression with child presence for rear-facing child restraints and 3 year-old and 6 year-old dummies would require the internal circuitry for suppression at $1 for the passenger side, a telltale light at $0.80, and either a weight sensor at $19 to $23, or an occupant presence sensor at $40 to $60. Thus, the total cost is $20.80 to $24.80 for the weight sensor or $41.80 to $61.80 for a presence sensor. Manufacturers may well determine that they want both systems to get the most information on occupant size and position. Thus, it is possible that the potential cost could be as much as the addition of these two systems or $60.80 ($1+0.80+19+40) to $84.80 ($1+0.80+23+60).

Current Compliance - Mercedes and BMW have a weight sensor that turns off the air bag when a low weight or no weight is in the right front passenger seat. It is assumed that this system could be updated to include up to 54 pounds with no additional cost. Sales of vehicles with these systems are estimated to be around 230,000 in the U.S. Thus, applying a factor of .985 (15.27 million/15.5 million) to these estimates results in cost estimates weighted by the percent of the fleet complying of $20.50 to $24.45 for the weight sensor (in Table VII-5) and $41.15 to $60.90 ($41.80 to $61.80 x .985) for a presence sensor.

2. One method to meet the low risk deployment test would cost $0 to minor costs for the driver side, assuming it is feasible with an air bag that could meet the test using one level of deployment output, for example a redesigned air bag with modified fold patterns and possibly a modified inflator.

If a dual or multi-stage inflation system based on crash severity and restraint use were used it would require a restraint use sensor at $2 to $5 for the passenger side, a dual or multiple level inflator at $4 to $20 per vehicle ($2 to $10 per side), and at the high end of costs, perhaps better crash severity sensing at $22.30 per vehicle ($11.15 per side) and a seat position sensor for the driver side ($5 for the driver side). Thus, the total cost range assuming no current compliance would be $0 to $26.15 ($10 + $11.15 + $5) for the driver side, $4 ($2 + $2) to $26.15 ($5 + $10 + $11.15) for the passenger side, and $4 to $52.30 for both sides.

A second method for meeting the low risk deployment test or some of the high speed tests would be to make improvements in the vehicle's crash pulse. The agency does not believe that manufacturers need to do both crash pulse improvements and multi-stage inflation systems to meet the standard, one of the two countermeasures would suffice. The cost estimate for crash pulse improvements is $27.15 per vehicle. Since this estimate is within the range of $4 to $52.30 for multi-stage inflation systems, we will use the wider range in the cost estimates.

Current Compliance - Based on the pre-MY 98 passing rates in Chapter IV (results of the 25 mph offset test in which 36 percent of the vehicles tested passed), it is estimated that 64 percent of all vehicle systems could require additional sensors for use with the dual or multi-level inflator to better refine speed sensing capabilities. For the average vehicle this would be $14.30 ($22.30 x .64) (assumed to be $7.15 for each side) to the high end of the range. Based on the passing rates in Chapter IV, about 25 percent of the fleet can meet the out-of-position test on the driver side, thus, the driver side average cost for a multi-stage inflator is estimated to be $1.50 to $7.50. No vehicles passed the low risk test on the passenger side. Some manufacturers (20% are assumed with pretensioners) currently have a restraint sensor on the passenger side, thus the average cost per vehicle is $1.60 to $4.00 for a restraint use sensor on the passenger side. Thus, the total cost of a dual or multi-level inflator system is $1.50 to $19.65 ($7.50 + $7.15 + $5) on the driver side and $3.60 to $21.15 on the passenger side for a total of $5.10 to $40.80 per vehicle (see Table VI-4 for a cost breakdown).

3. To meet the 25 mph belted offset barrier test would require either:

a) different sensors at $0 costs or additional sensors at a cost of $22.30 per vehicle, or

b) dual-stage or multi-stage inflators, which cost $52.30 per vehicle at the high end, as discussed previously.

Current Compliance -

a) If no new sensors are used, the low end of the range of cost is $0. Based on the passing rates in Chapter IV, about 36 percent of the pre-MY 1998 fleet tested passed this test. Thus, the average cost per vehicle, if additional sensors are used, is estimated to be $14.30 ($22.30 x 0.64), or $7.15 per side; or a manufacturer could use

b) dual-stage or multi-stage inflators, which after considering current compliance cost $40.80 per vehicle at the high end as discussed previously.

4. Most vehicles can meet the unbelted 5th percentile female dummy frontal barrier test at 25 mph. The agency has 4 MY 98/99 unbelted tests with the 5th female dummy at 25 mph. All four passed on the driver side and three of the four vehicles passed the test on the passenger side. The agency assumes those not in current compliance would require different fold patterns, tethering, or other minor design changes, which the agency believes can be met by all vehicles without incremental costs to the system.

5. To meet the unbelted 5th percentile female dummy frontal barrier test at 30 mph would require different fold patterns, tethering, or other minor design changes, which the agency believes can be met by some vehicles without incremental costs to the system. Other vehicles will require a multi-stage inflator with some type of sensor system to determine when a small female is in the driver seat as opposed to a larger occupant. A variety of sensors could be used to determine when a person, for example, a 5th percentile female, is too close to the air bag. The simplest system is a seat position sensor, which has been added in to the multi-stage inflator high end of the costs at $5 for the driver position. Those sitting too close to the steering wheel would receive the low level air bag deployment. The estimated cost to meet this test is from $0 to $52.30 per vehicle as discussed previously.

Current Compliance - The agency has tested 12 MY 1999 vehicles at 30 mph unbelted with the 5th female dummy (see Table IV-15). Five of the 12 (42 percent) passed on the driver's side and five of 11 (45 percent) passed on the passenger side. Inserting these estimates into the additional speed sensors calculation in Table VII-4 results in cost estimates for multi-level inflators of $18.95 for the driver side and $20.15 for the passenger side for a total of $39.10. Thus, after current compliance, the cost estimates are assumed to range from $0 to $39.10.

Test results were examined to determine whether any of the vehicles that met the 5th female unbelted test at 30 mph had failed the 25 mph offset deformable barrier test. Two of the vehicles that had passed the 5th female unbelted test at 30 mph (Saturn and Taurus) were tested in the 25 mph offset deformable barrier test and both passed that test. Thus, no adjustments were deemed necessary to the passing percentages and resulting cost estimates when test results would be combined in Chapter VIII.

6. It is assumed that manufacturers that don't currently meet the 0 to 35 mph belted test with the 50th male dummy would use pretensioners to achieve compliance. This is estimated to cost $18.70 to $22.60 per vehicle or $9.35 to $11.30 per seat.

Current Compliance - In the pre-MY98/99 data, 70 of 80 vehicles (88 percent) passed the 35 mph belted test on the driver side and 68 of 81 vehicles (84 percent) passed on the passenger side with the 50th male dummy. Thus, 12 percent are in noncompliance on the driver side and 16 percent on the passenger side. Thus, the incremental cost is estimated to be $1.10 to $1.35 ($9.35 to $11.30 x .12) for the driver side and $1.50 to $1.80 ($9.35 to $11.30 x .16) for the passenger side. Thus, the total cost per vehicle or $2.60 to $3.15.

Table VII-3
Estimated Per Vehicle Consumer Costs for Meeting Specific Tests
(Not weighted by current compliance rates)
(1997 Dollars)

Test	Cost
Suppression with child presence	Passenger side $20.80 to $24.80 for a weight sensor or $41.80 to $61.80 for a presence sensor $60.80 to $84.80 for both systems
Low risk deployment tests	Driver side $0 to $26.15 Pass. side $4 to $26.15 Total $4 to $52.30 Includes at high end - driver side seat position sensor, passenger side safety belt use sensor, both sides multi-level inflator and additional crash sensors
25 mph offset barrier test (belted)	Driver side $0 to $26.15 Pass. side $0 to $26.15 Total $0 to $52.30 per vehicle, High end assumes same as low risk deployment test
5th percentile female dummy in an unbelted 30 mph barrier test	Driver side $0 to $26.15 Pass. side $0 to $26.15 Total $0 to $52.30 High end assumes same as low risk deployment test
35 mph belted test with the 50th male	Driver side $ 9.35 to $11.30 Pass. side $ 9.35 to $11.30 Total $18.70 to $22.60

Table VII-4
Low Risk Deployment Test Costs
Driver Side

Additional speed sensors	$0 - $11.15
% in Noncompliance	64%
Costs	$0 - $7.15
Multi-level Inflator	$ 2 - $10
% in Noncompliance	75%
Costs	$1.50 - $7.50
Seat Position Sensor	$0 - $5
Total cost	$1.50 - $19.65

Passenger Side

Additional speed sensors	$0 - $11.15
% in Noncompliance	64%
Costs	$0 - $7.15
Multi-level Inflator	$ 2 - 10
% in Noncompliance	100%
Costs	$2 - $10
Restraint Use Sensor	$2 to $5
% in Noncompliance	80
Costs	$1.60 to $4
Total Cost	$3.60 - $21.15

Table VII-5
Average Consumer Costs for Meeting Specific Tests
After Considering Current Compliance
(1997 Dollars)

Test	Cost
Suppression with child presence (Passenger side)	Passenger side $20.50 to $24.45 for a weight sensor or $41.15 to $60.90 for a presence sensor $59.90 to $83.50 for both systems
Low risk deployment tests	Driver side $1.50 to $19.65 Pass. side $3.60 to $21.15 Total $5.10 to $40.80
25 mph offset barrier test (belted)	Driver side $0 to $19.65 Pass. side $0 to $21.15 Total $0 to $40.80
5th percentile female dummy in an unbelted 30 mph barrier test	Driver side $0 to $18.95 Pass. side $0 to $20.15 Total $0 to $39.10
35 mph belted test with the 50th male	Driver side $ 1.10 to $1.35 Pass. side $ 1.50 to $1.80 Total $ 2.60 to $3.15

B. Property Damage Cost

Consumers would experience repair cost savings if passenger-side air bags did not deploy in a crash with no one sitting in the right front seating position or, if a weight sensor were used, when there is less than a certain weight in the right front seat. The savings are to society, but they are realized mainly through insurance company payments and to consumers that don't have insurance or may not have collision coverage on their vehicles.

Based on NASS-CDS towaway crashes for 1996, there were 428,000 passenger car and light truck driver deployments. During 1996, the agency estimates there were 49 million passenger cars and light trucks on the road with driver air bags. An analysis of NASS-GES data for MY 1995 and later models indicate that of all police-reported crashes in which an air bag deploys, 82.26 percent are in towaway CDS-type crashes and 17.74 percent are in non-towaway crashes. Thus, the total number of driver air bag deployments in crashes in 1996 are estimated to be 520,300 (100/82.26 x 428,000). This assumes there are no air bag deployments in non-police reported crashes. What is needed for this analysis is a projection of the number of air bag deployments per year when the entire fleet is equipped with air bags and a distribution of air bag deployments over the life of a vehicle so that repair costs that might occur any time over the 20 year lifetime of a passenger car or 25 year life of a light truck can be discounted back to present value.

Since the vehicles in NASS 1996 with air bags are mostly newer vehicles, which drive more mileage than older vehicles, a rate of deployments per average vehicle would be exaggerated. An analysis taking vehicle miles traveled by age of vehicle x scrappage by age of vehicle x the total number of sales by age was compared to the same analysis for vehicles sold with air bags. These analyses were performed for both passenger cars and light trucks separately and were summed. The results of these analyses indicate that in 1996, the number of deployments multiplied by 2.54 would provide an estimate of the total number of deployments if all vehicles in 1996 had air bags. Thus, if all vehicles in 1996 had air bags, there would have been about 1,322,000 deployments in towaway and non-towaway crashes (2.54 x 520,300). In most vehicles currently on-the-road, both the driver and passenger side air bags deploy at the same time.

There were 192.1 million passenger cars and light trucks in the fleet for 1996. In the last assessment, the agency estimated a higher number of air bag deployments based on a projected increase in the number of vehicles in the fleet. However, manufacturers have started to raise the threshold speeds at which air bags deploy and that would lessen the number of deployments in the future. Not knowing the potential impact of raising thresholds, we decided not to increase the annual estimate of deployments based on increasing numbers of vehicles in the fleet. Thus, we estimate there would be about 1.322 million vehicles with air bag deployments annually.

Since all vehicles in the future will have both driver and passenger side air bags, there will be a similar number in both the driver and passenger side, unless there are technologies utilized to reduce deployments in certain situations. Based on NASS 1996, about 68 percent of the time there is no one sitting in the right front seat when the air bag deploys, and about 2 percent of the time the occupant in the right front seat is 6 years old or younger. Assuming a weight sensor by itself could detect weight for children representing those up to about age 6, a weight sensor could result in the suppression of 925,000 right front seat deployments (1.322 million x .70) a year.

Proximity sensors could also determine when no one is in the seating position or when someone is too close to the instrument panel. If the system is set up to suppress the air bag in these situations, a proximity sensor system could also result in cost savings by not deploying the air bag until it is needed.

To bring these estimates from a total fleet basis to an individual vehicle basis, one needs to determine the present discounted value of not having deployments at some time over the lifetime of the vehicle. The multiplier for the 7 percent discount factor is 0.7379 over the lifetime of passenger cars and 0.6956 over the lifetime of light trucks. Assuming 7.5 million sales for passenger cars and 8 million for light trucks by the year 2005 when this rule may become fully effective, the average discount factor is roughly 0.72 over a 22 year life.

If there were an estimated 1,322,000 deployments per year over a steady state sales of 15.5 million per year, 8.5 percent of the fleet will have an air bag deployment over their lifetime.

Based on costs from NHTSA's Vehicle Research and Test Center in replacing air bags during our test programs, the following costs are estimated.

Driver side:		
Air bag	\$350 to \$500	
Labor (Driver Side)	\$50	Assumed to be one hour at \$50 per hour
Total Driver Side	\$400 to \$550	
Passenger Side:		
Air bag	\$230 to \$800	
Instrument Panel	\$50 to \$300	
Windshield	\$600 to \$2,000 (not all vehicles need to replace the windshield)	
Labor (Pass. Side)	\$200 to 250	Assumed 4 hours without windshield replaced , 5 hours with windshield replaced
Total Pass. Side	\$480 to \$1,300 without the windshield replaced to \$1,130 to \$3,350 with the windshield replaced.	

For the passenger side, the lifetime repair cost savings for a weight sensor or presence sensor are estimated to range from \$20.60 to \$55.70 on the passenger side (\$480 to \$1,300 x 0.085 deployment rate x 0.72 discount rate x 0.70 unnecessary deployment rate) when the windshield does not have to be replaced and from \$48.40 to \$143.50 on the passenger side (\$1,130 to \$3,350 x 0.085 x 0.72 x 0.70) when the windshield does have to be replaced.

Totaled Vehicles - Commenters on the NPRM Preliminary Economic Assessment made the point that when a vehicle is totaled due to a crash, there is no savings to the consumer from not having the air bag deploy. Thus, the commenters indicated that the overall property damage savings of not having the passenger side air bag deploy when no one or small children were sitting in the front right seat, were overestimated.

When there is an air bag deployment, a percentage of the vehicles are totaled (not repaired) and sent to be recycled. If the repair cost of the vehicle, without considering repair costs for the passenger side air bag, would result in the vehicle being totaled anyway, the property damage savings from having a passenger air bag not deploy is meaningless. On the other hand, there are cases where the repair cost for the passenger side air bag, when added to the other repair costs for the vehicle, make the vehicle uneconomical to repair and it is declared a total loss.

Data from State Farm Insurance Company was requested to help quantify what percent of the vehicles would be totaled, and should not be assigned property damage savings. State Farm submitted the following estimates (see Table VII-6) based on data from the dual air bag Ford Taurus[10], which State Farm considered a typical vehicle in terms of air bag deployments and total losses. "Forced into a Total Loss" means that the additional cost of replacing the air bags and repairing subsequent damage to the instrument panel, windshield, etc., from deployment forced the vehicle to be totaled rather than repaired. These data were used in calculations (see Table VII-6 and VII-7) to determine the average influence of vehicles being totaled on potential property damage savings. The results of these calculations are that on average 50 percent of vehicles with deployments are repaired and an additional 10 percent of vehicles would not be forced into being totaled if the passenger side air bag did not deploy. Thus, 60 percent of the estimated property damage savings from not having the passenger side air bag deploy when unwanted would be realized by consumers.

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[10] The agency did not use these same data for light trucks since the repair rates for light trucks would be different than for passenger cars. For lack of better data, it is assumed that the resulting 60 percent estimate applies to both cars and light trucks.

Thus, after considering that on average 40 percent of the vehicles will be totaled and 60 percent repaired, the lifetime repair cost savings for consumers for a weight sensor or presence sensor are estimated to range from $12.35 to $33.40 (0.6 x $20.60 to $55.70) on the passenger side when the windshield does not have to be replaced and from $29.05 to $86.10 (0.6 x $48.40 to $143.50) on the passenger side when the windshield does have to be replaced.

Table VII-6
Effect of Air Bag Deployment on Total Losses
By Age of Vehicle

Age of Vehicle	Total Loss	Forced Into A Total Loss	Repaired
0	5%	3%	92%
1	5	5	89
2	10	18	73
3	14	18	68
4	25	19	56
5	34	26	40
6	49	30	21
7	77	19	4
8	85	15	0
9	86	14	0
10	88	12	0
11	88	12	0

Table VII-7
Average Percent of Vehicles Repaired
After an Air Bag Deployment

Passenger Cars					
Age	VMT	Survival	Weighted VMT	Air Bag % Repaired	
1	14,535	1.000	14,535	0.92	13372.2
2	13,924	0.993	13,827	0.89	12305.61348
3	12,846	0.982	12,615	0.73	9208.78356
4	11,378	0.964	10,968	0.68	7458.50656
5	10,749	0.935	10,050	0.56	5628.1764
6	10,119	0.892	9,026	0.4	3610.4592
7	9,490	0.831	7,886	0.21	1656.0999
8	8,860	0.753	6,672	0.04	266.8632
9	8,231	0.662	5,449	0	0
10	7,601	0.568	4,317	0	0
11	6,972	0.476	3,319	0	0
12	6,343	0.394	2,499	0	0
13	5,713	0.323	1,845	0	0
14	5,084	0.263	1,337	0	0
15	4,454	0.213	949	0	0
16	3,825	0.172	658	0	0
17	3,195	0.139	444	0	0
18	2,566	0.112	287	0	0
19	1,937	0.090	174	0	0
20	1,307	0.073	95	0	0
			106,953		53,507
					0.500

NOTE: 53,507/106,953 = 0.50

Table VII-8
Average Percent of Vehicles Forced into
A Total Loss as a Result of Deployment

Age	Forced into Total Loss %	Pass. Side % of Total Repair Cost	Pass. Side Forced Into Total Loss	Weighted Pass. Side Forced
1	0.03	0.65	0.0195	283.4325
2	0.05	0.65	0.0325	449.36229
3	0.18	0.65	0.117	1475.928324
4	0.18	0.65	0.117	1283.301864
5	0.19	0.65	0.1235	1241.2139025
6	0.26	0.65	0.169	1525.419012
7	0.3	0.65	0.195	1537.80705
8	0.19	0.65	0.1235	823.94013
9	0.15	0.65	0.0975	531.269895
10	0.14	0.65	0.091	392.880488
11	0.12	0.65	0.078	258.856416
12	0.12	0.65	0.078	194.933076
13	0.1	0.65	0.065	119.944435
14	0.08	0.65	0.052	69.528784
15	0.06	0.65	0.039	36.999378
16	0.04	0.65	0.026	17.1054
17	0	0.65	0	0
18	0	0.65	0	0
19	0	0.65	0	0
20	0	0.65	0	0
				10,242
				0.096

Note: 65% factor is the weighted estimate of the property damage savings from the passenger side compared to both driver and passenger side, since "Forced into a total loss" is determined from a dual air bag car and only the passenger side air bag may not deploy.
Calculated as [(480 + 1300)/2]/[(400 + 500)/2 + (480 + 1300)/2].

10,242/106,953 = 0.096

Only Mercedes and BMW currently have a weight sensor that turns off the air bag when a low weight or no weight is in the right front passenger seat. It is assumed that this system could be updated to include up to 54 pounds with no additional cost, and that current weight sensor sales are around 230,000 a year in the U.S. Thus, applying a factor of .985 (15.27/15.5 million) to these estimates results in cost estimates weighted by the percent of the fleet complying of $12.15 to $32.90 without replacing the windshield and $28.60 to $84.80 when the windshield must be replaced.

Table VII-9
Estimated Property Damage Savings
(1997 Dollars)

System	Driver Side	Passenger Side	Total
Suppression with child presence -	$0	$12.15 to $32.90 w/o replacing windshield $28.60 to $84.80 replacing windshield	$12.15 to $32.90 w/o replacing windshield $28.60 to $84.80 replacing windshield
Suppression when out of position only	negligible	negligible	negligible
Low risk deployment test	$0	$0	$0
25 mph offset test	$0	$0	$0
35 mph belted 50^{th} test	$0	$0	$0
5th percentile female dummy in an unbelted 25 or 30 mph barrier test	$0	$0	$0

C. Total and Net Costs

It is estimated that the average number of passenger cars and light trucks sold per year affected by this final rule will be 15.5 million[11]. With 15.5 million vehicles potentially being affected, it only takes an average cost of $6.45 to reach the $100 million threshold. Given that several technologies cost more than $6.45, this will be a significant rulemaking.

For each technology a net cost is estimated on a per vehicle basis and a total cost is derived assuming that all vehicles that don't currently have that technology, or pass the test already, use that technology. The net cost calculation comes from taking the consumer cost and subtracting the present discounted value (discounted at 7 percent) of savings from not having to repair vehicles in cases of unnecessary air bag deployments.

For the **suppression with child presence using a weight sensor,** the average costs are estimated to range from $20.50 to $24.45 per vehicle. Property damage savings range from $12.15 to $32.90 without replacing the windshield and from $28.60 to $84.80 when the windshield is replaced. Thus, weight sensors will most likely be cost effective for consumers. The net ranges are from costing $12.30 to saving $12.40 without replacing the windshield and from saving $4.15 to $64.30 for those vehicles needing the windshield replaced. Assuming annual new car and light

[11] The current air bag requirement and this final rule are not applicable to light trucks and vans that are over 8,500 GVWR or 5,500 pounds unloaded vehicle weight. Sales of these vehicles vary considerably from year to year, usually less than 500,000 per year. More than half of these vehicles are equipped with air bags. Sales predictions for MY 2003 and later range between 15.5 and 16 million vehicles annually. Thus, we predict that about 15.5 million vehicles will be affected by these requirements.

truck sales of 15.5 million units, the total annual net ranges from a cost of $191 million to a cost savings of $192 million if no vehicle needed the windshield replaced after an air bag deployment and from a cost savings of $64 million to $997 million if all vehicles needed the windshield replaced after an air bag deployment.

For the **suppression with child presence based on a occupant position sensor,** the costs are estimated to range from $41.15 to $60.90 per vehicle. Property damage savings range from $12.15 to $32.90 without replacing the windshield and from $28.60 to $84.80 when the windshield is replaced. The net costs could range from $8.25 to $48.75 per vehicle without replacing the windshield and the net costs could be as high as $32.30 and the net savings could be as high as $43.65 for those vehicles needing the windshield replaced after an air bag deployment. Assuming annual new car and light truck sales of 15.5 million units, the total annual net cost could range from $128 to $756 million if no vehicle needed the windshield replaced after an air bag deployment and total annual net cost could be as high as $501 million and the net savings could be as high as $677 million if all vehicles needed the windshield replaced after an air bag deployment.

For the **low risk deployment system** the costs are estimated to be from $5.10 to $40.80, and there are no property damage savings unless a higher threshold is included at the same time, thus the net costs are the same. Thus, total costs for 15.5 million vehicles would be from $79 million to $632 million.

For the **25 mph offset barrier test** the costs are estimated to be from \$0 to \$40.80 per vehicle and there are no property damage savings. Thus, the total net costs for a 15.5 million vehicle fleet range from \$0 to \$632 million.

For the **35 mph belted 50th male dummy barrier test**, the costs are estimated to be \$2.60 to \$3.15 and there are no property damage savings. Thus, the total net costs for a 15.5 million vehicle fleet are \$40 million to \$49 million.

For the **5th percentile female barrier test** at 30 mph the costs are estimated to be \$0 to \$39.10 and there are no property damage savings. Thus, the total net costs are \$0 to \$606 million.

For those technologies that could potentially have a net consumer savings (weight sensors or possibly position sensors for the right front passenger side), one issue is whether the market would result in the voluntary installation of these technologies without a Federal requirement. Two German companies (Mercedes and BMW - which are at the high end of the price market and probably have high air bag crash repair costs) have introduced weight sensors, partially due to the requests of insurance companies in Europe. There are many factors that a manufacturer would consider before adding a feature that added costs, but saved money for the average consumer in the long run. These include: the impact of price increases on new vehicle sales, aftermarket sales (fewer deployments mean less aftermarket parts sales), reliability, consumer perceptions about whether both air bags should have gone off in the crash, and whether American consumers on lower priced vehicles can perceive the long term benefits if they feel they will never be in a severe enough crash to deploy the air bag. Weight sensors and position sensors are new technologies that most consumers haven't been exposed to, and currently aren't aware of their potential benefits. Thus, there is little or no current consumer demand for the product. There may currently be a market failure due to imperfect knowledge by consumers and the fact that new vehicle purchasers would pay for any cost increases due to their installation, but most of the benefits accrue directly to insurance companies through lower collision loss payments. Consumers are dependent upon insurance companies to ultimately pass on these cost reductions to policy holders through premium reductions. Consumers may be uncertain that this will occur. Assuming that competition in the insurance market causes this pass-through to occur, one effect of this proposal may be merely to expedite the installation of some devices that are cost-beneficial for society and would ultimately be demanded by the market anyway.

Table VII-10
Net Consumer Costs (Savings) Per Vehicle
(1997 Dollars)

System	Consumer Cost At Time of Purchase	Property Damage (Savings)	Net Consumer Costs (Savings)
Suppression with child presence - with a weight sensor	$20.50 to $24.45 Passenger side	($12.15 to $32.90) w/o replacing windshield ($28.60 to $84.80) replacing windshield	$12.30 to ($12.40) w/o replacing windshield ($4.15 to $64.30) replacing windshield
Suppression with child presence - with a presence sensor	$41.15 to $60.90 Passenger side	($12.15 to $32.90) w/o replacing windshield ($28.60 to $84.80) replacing windshield	$8.25 to $48.75 w/o replacing windshield $32.30 to ($43.65) replacing windshield
Low risk deployment test	$5.10 to $40.80	$0	$5.10 to $40.80
25 mph offset test	$0 to $40.80	$0	$0 to $40.80
35 mph belted 50th test	$2.60 to $3.15	$0	$2.60 to $3.15
5th percentile female dummy in an unbelted 30 mph barrier test	$0 to $39.10	$0	$0 to $39.10

D. Compliance Test Costs

This section discusses the estimated costs for the agency or for a manufacturer to perform compliance tests. Costs are in 1997 dollars. Most of these tests, or tests like these, are already run by the manufacturers and may not be incremental costs for them. This final rule would standardize a minimum set of tests run by the industry on air bags.

Vehicle Crash Tests

In the NPRM, the agency proposed 14 potential vehicle crash test conditions:

12 potential rigid barrier tests: 3 angles (head-on, 30 degrees left and 30 degrees right) for 4 conditions (unbelted 50th male, belted 50th male, unbelted 5th female, and belted 5th female), and 2 potential tests using a deformable offset barrier (left and right side of the vehicle) with belted 5th percentile female dummies. Commenters stated that there were too many vehicle crash test conditions.

For the SNPRM, the agency proposed 9 potential vehicle crash test conditions for both Alternative 1 and Alternative 2.

For the final rule, the agency is requiring 7 potential vehicle crash tests [an unbelted test for the 50th male perpendicular and at +/- 30 degrees (3 tests), an unbelted test for the 5th female, a belted test for the 50th male and 5th female, and an offset test with the 5th female. There are the same number of tests for Option 1 and Option 2. Compliance test costs are:

The final rule includes a barrier test with neck injury criteria. A current compliance test, without neck injury costs about $18,000[12] for one test. With neck injury measurements, it would cost about $18,600 for one test. The current agency standard also provides for an unbelted sled test alternative with the 50th percentile male dummy. Almost all manufacturers are using the sled test. The sled test already includes neck data and costs about $16,000 to run. NHTSA buys a vehicle to make the sled buck for testing. The incremental cost of the barrier test over the sled test is $2,600. Manufacturers can save testing costs by using the sled because they will do multiple tests using the same sled buck.

The costs of running an offset frontal deformable barrier test is also around $18,600. There are also costs for the deformable face, which is destroyed with each test, of $1,025. Thus, the total cost for running the offset test is $19,625.

If the government ran all of these tests for one make/model, it would have to purchase 7 vehicles at an average cost of $20,000 each or $140,000. However, NHTSA need not run all of these crash conditions for a make/model chosen for testing. The compliance test costs for running all seven tests is $131,225 ($18,600 x 6 + $19,625). Total costs for the tests and vehicles would average $271,225 for the high speed vehicle tests.

Currently, the standard requires certification to the 3 belted 50th percentile male dummy tests and a sled test. The total cost of these tests are $151,800 ($18,600 x 3 + $16,000 + 4 vehicles x

[12] All cost estimates are from NHTSA's costs for a contractor to perform these test.

$20,000). Thus, the potential incremental cost for high speed tests is $119,425 per make/model, if all of the tests were run.

Cost estimates for NHTSA do not reflect the cost estimates for manufacturers. While the average new vehicle price is around $20,000, manufacturers developing all new models may decide to use a few prototype vehicles for development testing purposes. Prototype vehicles can easily cost $200,000. The agency believes that most manufacturers are already running many of the tests required, including the offset tests and have test facilities available to run these tests. Manufacturers must certify that their vehicles meet the standard, but are not required to run the test to prove certification.

Static Tests

Tests for Static Suppression - Passenger Side

For each set of out-of-position tests there would be a 2 hour set up time to inspect and clothe the dummy, prepare the vehicle, set the cameras, etc. Then, it is estimated to take 30 minutes per test configuration, with three to four different positions, per child restraint. It is also assumed to take 30 minutes to set up the dummy for each of the out-of-position tests that are not in a child restraint. Labor costs are estimated at $31 per hour for technicians and $53 per hour for engineers. It is assumed that one technician and one engineer would run the tests for a total of $84 per hour test cost. The agency would purchase a separate vehicle to do the static tests at an average cost of $20,000.

Infants

The 12-month old dummy is put in the child seat, the seat in the vehicle, the handle is moved to different positions, a towel or blanket is put over the top of the infant in a few positions, and the vehicle seat is moved to three different positions. The door must be closed and the light monitored after each change. In addition, the agency is requiring a 5th percentile female dummy test in the right front seat to make certain that the system recycles from the air bag deactivated situation for the child restraint to the air bag activated situation for the adult situation. The agency suspects that manufacturers will use a 5th percentile female, rather than a dummy, as a cheaper quicker solution to this requirement.

The agency has established a specific set of child restraints on the market for its testing:

1) 1 car bed in its nominal design position,

2) 11 different rear facing child restraints, each of which would be tested with and without the base, so a possible total of 22 child restraints each tested at 3 different positions (belted facing rearward, unbelted facing forward, and unbelted facing rearward) for a total of 66 tests,

3) 7 convertible seats each tested at 4 different positions (belted and unbelted, facing forward and rearward) for a total of 28 tests.

Thus, there is a total of 95 tests[13] (1 + 66 + 28). For costing purposes, there is a total of 30 test configurations (1 + 22 + 7).

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[13] The number of tests can be counted in different ways. One could count each of the three vehicle seat positions separately, three towel positions, two handle positions and sun screen positions separately for the infant restraints, and add in the 5th female activation tests, which could increase the numbers by up to 6 times the numbers shown.

If all the different child restraints for infants and configurations possible were tested, the total cost would be $1,428 (2 hours set up + 30 x 30 minutes = 17 hours x $84). Is it possible that manufacturers could reduce the number of tests by 60 percent if they use a weight sensor and determine that the belted test is the worst case scenario and they don't have to test the unbelted condition.

3-year-old and 6-year-old Dummies

The testing using the 3-year-old dummy includes 7 convertible seats and 4 booster seats with the dummy in the child seat and an additional 9 tests with the unbelted dummy in different positions for a total of 20 tests. The testing using the 6-year-old dummy includes 4 booster seats with the dummy in the child seat and an additional 4 tests with the unbelted dummy in different positions for a total of 8 tests. Combining the 3-year-old and 6-year-old dummy test for automatic suppression, there are 28 tests. The total cost would be $1,344 (2 hours set up + 28 x 30 minutes = 16 hours x $84).

Out of Position Test of Low Risk Deployment

It is estimated to take about 3 hours to set up for this test to place the dummy, hook up the dummy instrumentation, camera coverage, etc. Then it is estimated to take 2 hours per test to position the dummy, run the test, remove and install a new air bag, instrument panel and windshield, and do pre and post photographs. Total labor time is 5 hours or $420 (5 x $84) plus the cost of a new air bag, instrument panel and windshield, if needed of $400 to $550 for the driver side and $1,130 to $3,350 for the passenger side. Two positions are run for the driver side. Two positions are run for the passenger side for both the 3-year-old and 6-year-old dummy, for a total of 4 tests on the passenger side. The total cost for the low risk tests is estimated to be $1,640 [2 x ($420 + $400)] to $1,940 for the driver side and $6,200 to $15,080 for the passenger side for a total of $7,840 to $17,020.

Out of Position Test for Dynamic Suppression

This is an optional test, which will have to be specified by the manufacturer to provide a fair test of the specific system. For this test, the manufacturer would have to petition the agency to allow a test for it's system. Since the agency doesn't have a test procedure, the cost of the test cannot be estimated. If it involves crashing a vehicle, the test costs would be at least as much as the vehicle crash test costs discussed above.

Total Testing Costs

Total testing costs to the agency to run one vehicle through all of the tests, assuming the use of the vehicle crash tests, the static suppression tests for the passenger side, and low risk for the driver side are about $276,000 ($271,225 + $1,428 + $1,344 + 1,940). If the low risk option is chosen by the manufacturer for the driver and passenger side, total testing costs to the agency to run one vehicle through all of the tests are $278,000 to $288,000 ($271,225 + $7,840 to $17,020). These assume eight vehicles must be purchased (seven for the vehicle crash tests and one for out-of-position testing).

This is 80 percent higher than the current cost to the agency to run all of the current potential tests, which cost $151,800. Of course, the agency does not have to run all of these tests, it may only run what it believes might be the worst case conditions to check for compliance.

Dummy Costs

Most manufacturers already own a variety of dummies for use in research testing. The 1998 list costs for fully instrumented dummies are shown in Table VII-11. Not all of the instrumentation is required for this proposal. Several of the load cells and accelerometers provide information that is not required by the proposal on areas such as lower limbs, etc. Cost estimates for the dummies as required in the final rule are also shown in Table VII-11.

Table VII-11
Dummy Costs ($1998)

	Fully Instrumented Dummy			**Dummy with Instrumentation In Final Rule**		
	Dummy	**Instrumentation**	**Total Costs**	**Dummy**	**Instrumentation**	**Total Costs**
CRABI-12 month	$8,300	$42,500	$50,800	$8,300	$15,500	$23,800
HIII-3 yr.	36,400	62,300	98,700	36,400	15,500	51,900
HIII-6 yr.	31,200	72,900	104,100	31,200	61,400	92,600
HIII-5th female	33,400	99,100	132,500	33,400	69,200	102,600

Note that costs for laboratory overhead and profit are not considered in many of the above test estimates.

E. Leadtime

The NHTSA Reauthorization Act of 1998 directs the agency to issue a final rule not later than September 1, 1999 and to have a phase-in beginning not earlier than September 1, 2002 and no sooner than 30 months after the issuance of the final rule, and be fully effective by September 1, 2005. However, if the final rule cannot be completed by that date, it must be issued no later than March 1, 2000, and NHTSA is authorized to delay the phase-in starting date to not later than September 1, 2003 and to delay making the final rule fully effective until September 1, 2006.

In the SNPRM, the agency realized the final rule would not be issued until March 1, 2000. The agency proposed that the phase-in start on September 1, 2002 (the beginning of Model Year (MY) 2003, and that the rule be fully effective on September 1, 2005 (MY 2006).

Vehicle leadtime is a complex issue, especially when it involves advanced technology and designs that are still under development. In three different formal actions, the agency has gathered information concerning leadtime. First, the agency held a public meeting on advanced air bags on February 11 and 12, 1997, in Washington D.C. (See Docket NHTSA-97-2814). Second, NHTSA contracted with JPL to conduct an independent analysis (See 97-2814) concerning the readiness of the advanced air bag technologies. Third, the agency contracted Management Engineering Associates (MEA), an engineering management consulting company, to conduct a feasibility study on advanced air bag technologies (See 97-2814).

These three sources of information indicated the same basic time schedules: currently available technological solutions such as seat sensors, seat belt buckle sensors, dual-stage inflators and advanced air bag fold patterns, can be and will be in production between model year 1999 and model year 2002. More sophisticated systems such as dynamic occupant position sensing systems may not be available until after September 1, 2001.

NHTSA has also held numerous meetings with and sent information requests to the vehicle manufacturers and suppliers. The companies have shared confidential information with the agency about their ongoing development efforts and future product plans. The agency notes that leadtime for technology still under development typically depends on two things: initial development to demonstrate that a concept is feasible, and then further development to apply the technology to a specific vehicle design. These typically involve efforts both by suppliers and by vehicle manufacturers. In this field of technology, it appears that much of the innovative development is being borne by the component suppliers, based on performance specifications defined by the vehicle manufacturers. First the systems are designed, tested and produced in a limited quantities by the component manufacturers. Next these systems are turned over to the vehicle manufacturers. The vehicle manufacturers then conduct prototype design verifications, conduct production level equipment verification and finally complete production and include the systems in their new vehicles. On the average, MEA estimates the vehicle manufacturers' cycle could take 36 months.

The suppliers and vehicle manufacturers have, however, been working on various advanced technologies for several years. Thus, to a large degree, leadtime is dependent on where the suppliers and vehicle manufacturers are currently in their development and implementation efforts. NHTSA believes that different suppliers and vehicle manufacturers are at different stages with respect to designing improved air bags. NHTSA believes that these differing situations can best be accommodated by phasing in requirements for advanced air bags.

Leadtime is examined for different vehicle types.

1) Original vehicle manufacturers - Most of the vehicle manufacturers requested that the agency provide the longest leadtime available under the Act. Many of the manufacturers also requested that if the 35 mph belted test were to be included, that it be phased-in after the requirements for the Act are finished. In addition, they noted that neither they nor NHTSA had any test data for the 5^{th} female dummy at 35 mph belted and that the possibility of adding that test be considered in a future rulemaking. The agency considered a variety of leadtimes for the final rule. Mainly they included a two phase process, where some set of requirements would be required to be met in Phase 1 and a stricter set would be met in Phase 2. Under consideration were:

Phase 1: 25 mph unbelted tests for 5^{th} and 50^{th} dummies, Phase 2: 30 mph unbelted tests for both

Phase 1: 25 mph unbelted tests for 5^{th} and 50^{th} dummies, Phase 2: 35 mph belted test for 50^{th} and a separate rulemaking for the 5^{th} female for a 35 mph belted test.

Phase 1: 30 mph unbelted test for 50^{th} dummy, Phase 2: 30 mph test for the 5^{th} dummy.

Taking into account all of the available information, the agency set the final rule phase-in schedule in accordance with the following implementation schedule having a 25 mph unbelted test during Phase 1 and a 35 mph belted test for the 50^{th} male dummy during Phase 2. All of the other tests are included in the Phase 1 period.

Phase-in Alternatives

Model Year	SNPRM	**Final Rule, Phase 1**
2003	25% with carryover	0
2004	40% with carryover	35% with carryover
2005	70% with carryover	65% with carryover
2006	100% fully effective	100% with carryover
2007		fully effective, including small manufacturers, multi-stage and alterers
		Final Rule, Phase 2
2008		35% with carryover
2009		65% with carryover
2010		100% with carryover
2011		fully effective, including small manufacturers, multi-stage and alterers

b) Leadtime for limited-line manufacturers. In the SNPRM, the agency proposed a one-year delay for manufacturers selling 2 or less models in the United States. They could choose as an option to have full compliance in MY 2004. For the final rule, this alternative is allowed for MY 2005 for the first phase-in and in MY 2008 for the second phase-in .

c) Leadtime for small manufacturers. As mentioned in Chapter IX, small vehicle manufacturers are typically at the end of the line for these advanced technologies. Part of the reason is their smaller engineering staff and part of the reason is economics. The smaller manufacturers don't have the funds to test out new technologies. Similarly, suppliers are trying to assure a market with larger manufacturers first. Once the suppliers and manufacturers have advanced on the learning curve with a new technology, then it becomes a manageable task for suppliers to consider introducing the technology for smaller manufacturers with different vehicle conditions.

Cosvam stated that limited line manufacturers need until the end of the main phase-in to comply with the final rule. The agency is providing small manufacturers (as defined by having sales of less than 5,000 vehicles worldwide) with as much lead time as possible under the Act by not requiring that all of their vehicles meet the fully effective date until the end of the phase-in or MY 2007 for the first phase-in and MY 2011 for the second phase-in.

d) Leadtime for second-stage manufacturers and alterers. In the SNPRM, the agency proposed that multi-stage manufacturers and alterers be allowed an option of 100% compliance of their fleet at the end of the phase in MY 2006. In the past, commenters such as Atwood Mobile Products (98-4405-#48) requested that second stage manufacturers be given a one year extension after full compliance by the original equipment manufacturers (OEM's) to obtain the information from the OEM's and complete their testing. As discussed in Chapter IX, several additional commenters made the same request to the SNPRM. The agency is providing multi-stage manufacturers and alterers with as much lead time as possible under the Act by requiring that all of their vehicles meet the fully effective date at the end of the phase-in or MY 2007 for the first phase-in and MY 2011 for the second phase-in.

An issue which is closely related to leadtime for advanced air bags is the time when amendments providing temporary reductions in Standard No. 208's performance requirements should expire. The amendment permitting manufacturers to provide manual on-off switches for air bags in vehicles without rear seats or with rear seats too small to accommodate a rear facing infant seat is scheduled to expire on September 1, 2000. In the final rule, manual on-off switches will not be permitted starting on September 1, 2008 .

The amendment providing a generic sled test alternative to Standard No. 208's unbelted barrier test requirements expires on September 1, 2001. The 1998 Act states; "...the requirements of S13 of Standard No. 208 shall remain in effect unless and until changed by the rule required by this subsection." Thus, the agency must coordinate the timing of advanced air bags, with the existing provisions of S13, allowing the generic sled test to continue until vehicles can meet the advanced air bag requirements. Consistent with the Act, NHTSA is extending the dates so that the temporary amendments are phased out as the upgraded requirements are phased in. During the phase-in, the temporary amendment for the sled test alternative will not be available for vehicles certified to the upgraded requirements, but would be available for other vehicles.

VIII COST-EFFECTIVENESS ANALYSIS

The intent of this rulemaking is to minimize risks caused by air bags to out-of-position occupants, and to enhance the overall benefits provided to occupants in most crashes. To achieve these goals, NHTSA is proposing to establish test procedures that broaden the scope of the current standard to ensure that occupants of various sizes and ages are properly protected under a variety of crash circumstances.

Three vehicle crash tests are required to enhance air bag benefits. Frontal rigid barrier tests would be conducted for both 50th male and 5th female dummies, in both belted and unbelted modes. The oblique rigid barrier test would be conducted for unbelted 50th male dummies. The third test is a restrained 25 mph offset deformable barrier test, which has been added to simulate the circumstances of an out-of-position occupant in an offset crash and measure crash sensing capabilities at lower speeds. This test would be conducted with 5th percentile female belted dummies. Methods for meeting the frontal barrier, offset, and oblique tests include multi-stage inflators, improved sensors, and modified air bag designs.

The current analysis examines three alternative groupings of these tests. These groupings are summarized in Table VIII-A The reader is also referred to Figures I-2, I-3, and I-4 in Chapter I.

Table VIII-A
Summary of High Speed Test Requirements for Alternatives 1, 2 and 3

TYPE	SPEED	BELT	DUMMY	ALT 1	ALT 2	ALT 3
Frontal Rigid Barrier	0-30mph	Belted	50th Male	X	X	
Frontal Rigid Barrier	0-35mph	Belted	50th Male			X
Frontal Rigid Barrier	0-30mph	Belted	5th Female	X	X	X
Frontal Rigid Barrier	20-30mph	Unbelted	50th Male		X	
Frontal Rigid Barrier	20-30mph	Unbelted	5th Female		X	
Oblique Rigid Barrier	20-30mph	Unbelted	50th Male		X	
Offset Barrier	0-25mph	Belted	5th Female	X	X	X
Frontal Rigid Barrier	20-25mph	Unbelted	50th Male	X		X
Frontal Rigid Barrier	20-25mph	Unbelted	5th Female	X		X
Oblique Rigid Barrier	20-25mph	Unbelted	50th Male	X		X

Within each alternative grouping, all of these tests must be passed in order to prove compliance with the requirements to enhance the performance of air bags.

In addition to these new tests, the final rule will upgrade the injury criteria for the existing frontal barrier tests by changing the way head injuries are measured, reducing allowable chest deflection, and including a measure of neck injury. The final rule also eliminates the sled test alternative to the barrier test.

The risk of injury from air bags arises when occupants are too close to the air bag when it inflates. Generally, those most at risk from injury are infants, children, and small statured adults. To address these concerns, tests employ crash dummies representing infants, 3-year olds, 6-year olds, and 5th percentile female drivers. A variety of tests are required to protect these at-risk occupants. Manufacturers must certify compliance with one of these individual tests for each risk group (infants, children (represented by both 3 and 6 year old dummies), out-of-position drivers). The options for each risk group are summarized in Figure I-1 of this analysis.

As a practical matter then, manufacturers will have to take measures which will assure they can pass the tests designed to enhance air bag safety plus some combination of tests that address the four representative categories of occupants at risk from air bag injuries. For this analysis, these groups of possible solutions will be referred to as "compliance options". Two groups of compliance options have been identified from the basic tests for each Alternative. A basic assumption defining these compliance options is that, where possible, manufacturers would use the same systems to address testing for all risk groups. Thus, for example, multi-stage inflators would provide benefits for all occupants, regardless of age. However, infants would probably not be covered by multi-stage inflators without the use of a RFCSS detection sensor because the final rule requires rear facing child safety seats to meet a separate low risk deployment test for all inflation levels up to 40 mph. It is thus likely that some form of suppression technology will be required to pass the requirements for infants.

As noted above, compliance with the new tests intended to enhance air bag benefits would be mandatory. All of the alternatives include the up to 25 mph 5th percentile female dummy offset barrier test and the enhanced criteria frontal barrier tests. A number of technological solutions would enable manufacturers to meet these tests, including added sensors and multi-stage inflators, but manufacturers may meet the enhanced criteria frontal barrier tests with modified air bag designs.

The two optional tests potentially cover different low speed at-risk groups. The test for suppression with child presence (test reference #1 in Tables VIII-1 through VIII-12) can be conducted using the infant, 3 year old, and 6 year old dummies and thus addresses at-risk infants and children. The low-risk deployment test (test ref. #2) could be used to certify compliance for all risk groups. However, at this time the agency does not believe that an infant dummy in a RFCSS could pass the criteria with a low-risk air bag. Thus, a weight sensor has been added to this compliance option. In the NPRM, NHTSA also discussed a dynamic out-of-position test which was conducted using dummies representing all groups except infants. However, this test has been excluded from the final rule analysis because it requires manufacturers to file a separate petition proposing specific test procedures for accessing their particular dynamic system. Thus, the suppression test covers both infants and non-infant children, and the low risk deployment test covers all categories except infants. The two compliance options examined here represent all logical combinations of these tests that would prove compliance for all basic at-risk groups.

In Table VIII-1, a range of cost estimates has been developed for each technology solution grouped under each test option. At the bottom of Table VIII-1, these costs are summarized for the two compliance options for each of the three alternatives resulting in six Compliance Scenarios. This analysis reveals potential compliance costs ranging from about $21 to $128 per vehicle. The variation in cost is a function of both the technologies used and variation in cost estimates from different sources.

The first compliance option (Compliance Option #1) assumes a scenario in which manufacturers meet requirements for out-of-position drivers with low risk deployment (Test ref. #2). For passengers, including infants, weight sensors are assumed (Test #1). Incremental costs for the Compliance Scenarios with Compliance Option #1 range from $21 to $124 for Alternative 1, $21 to $124 for Alternative 2, and $23 to $128 for Alternative 3 (see Table VIII-1). The range reflects different cost estimates provided by manufacturers or engineering tear-down studies, as well as different approaches to system design. Detailed discussion of the sources for cost estimates for technologies that determine this range as well as for cost ranges associated with other compliance options is included in Chapter VII.

The second compliance option (Compliance Option #2) assumes that manufacturers use a weight sensor costing $21 to $24 for infants and meet all other out-of-position requirements by meeting the low risk deployment test (Test #2). Technological solutions which could enable manufacturers to pass the low-risk test include modified air bag fold patterns and/or inflators, and multi-stage inflators. The total cost estimate for the Compliance Scenarios with Compliance Option #2 ranges from $24 to $65 for Alternative 1, $24 to $65 for Alternative 2, and $27 to $68 for Alternative 3 (see Table VIII-1).

As discussed in Chapter VII, some of the countermeasures may result in a significant savings in property damage costs because they prevent unnecessary air bag deployments which result in replacement costs for the air bag and often destroy front windshields as well. Estimates of these savings are summarized in Table VIII-2. Note that the range of estimates in this table and all subsequent tables match the technologies used to derive the range of high and low costs from Table VIII-1, and are not necessarily the highest and lowest possible property damage impacts. This linkage to the range of costs on Table VIII-1 is necessary in order to assure that costs and benefits are consistently associated with the same vehicle changes.

In Table VIII-3, the costs from Table VIII-1 are combined with the present discounted value of property damage savings from Table VIII-2 to produce the net cost or monetary benefit from each technology and compliance option. The results indicate that there are net costs for the Compliance Scenarios with Compliance Option #1, but the scenarios with Compliance Option #2 have potential property damage savings that could exceed the consumer's cost for changes needed to comply with the tests.

In Table VIII-4, the net per-vehicle costs from Table VIII-3 are multiplied by 15,500,000, the estimated annual steady state sales of passenger cars and LTVs (see Chapter VII), to produce an estimate of the total annual net consumer costs of the alternative new testing requirements. Estimates range from a cost of $663 million to a net savings of $303 million.

In Chapter VI, safety benefits are derived for each alternative test procedure. These benefits are summarized in Tables VI-34 through VI-39. In Tables VIII-5 and VIII-7, those benefits are summarized for the technologies and compliance options used in the previous tables. As with Table VIII-2, the range is defined by the high and low estimates of costs in Table VIII-1, with the range of benefits maximized for those cases where more than one technology had the same cost. Note that in many cases, different technologies are addressing the same problem, but that some address larger target populations. To the extent that these technologies are combined under a specific compliance option, their benefits are thus not additive, and the maximum benefit for that compliance option is defined by the system with the largest safety benefit. For example, under Alternative 1, Compliance Option #2, the high range driver costs include the multi-stage inflators for the low risk deployment test, the frontal barrier test, and the 25 mph offset barrier test. However, the 58 lives saved by multi-stage inflators for the 25 mph offset barrier test encompass those that would be saved by the similar equipment installed to meet the other tests. Therefore, the potential benefit from multi-stage inflators are only counted once.

The resulting estimates indicate that Alternative 1 could produce results ranging from 233 fewer lives to 211 more lives saved. Alternative 2 could produce a potential increase in benefits from

162 to 230 more lives saved. Alternative 3 could produce results ranging from 233 fewer lives to 215 more lives saved. These comparisons are to pre-MY 1998 air bags that met 30 mph belted and unbelted tests. Potential benefit reductions relative to the pre-MY 1998 baseline occur under the less demanding 25 mph high speed test required under Alternatives 1 and 3. In higher speed crashes where fatalities are more likely, the 25 mph systems could provide less protection. For nonfatal injuries, which tend to occur at lower speeds, all three Alternatives show only potential benefits. These benefits range from 1,710 to 1,902 injuries prevented for Alternative 1, from 498 to 2,059 for Alternative 2, and from 1,966 to 2,388 for Alternative 3.

In Tables VIII-6 and VIII-8, the safety benefits from Tables VIII-5 and VIII-7 have been discounted at a 7 percent rate to express their present value. Seven percent is used because it is the rate required for use in Regulatory Evaluations by the Office of Management and Budget (OMB Circular A-94, 10/29/92).

As a primary measure of the impact of these alternatives, this analysis will measure the cost per fatality, or fatality-equivalent saved. In order to calculate a cost per equivalent fatality, nonfatal injuries must be expressed in terms of fatalities. This is done by comparing the value of preventing nonfatal injuries to the value of preventing a fatality. Comprehensive values, which include both economic impacts and lost quality (or value) of life considerations will be used to determine the relative value of fatalities and nonfatal injuries. These values were taken from the most recent study published by NHTSA[1]. In Table VIII-9, the process of converting nonfatal injuries is illustrated. The upper part of Table VIII-9 shows the comprehensive values used for each injury severity level, as well as the relative incidence-based weights for two groups of nonfatal injuries, MAIS 2-5 and MAIS 3-5. These are the 2 groupings of injuries measured for the safety enhancement test procedures and the at-risk test procedures respectively. The table shows that an average MAIS 2-5 injury is the equivalent of 0.10 fatalities, and that an average MAIS 3-5 injury is the equivalent of 0.22 fatalities.

Because safety benefits are composed of differing portions of these groups for each occupant category within each compliance option, an average impact must be calculated for each separate category. The lower left portion of Table VIII-9 shows the portion of nonfatal injury benefits that are associated with the at-risk group for each occupant category under each compliance option. These portions (Pr) were used to weight the MAIS 3-5 injury equivalent (0.22). The remaining weight (i.e., 1- Pr), were used to weight the MAIS 2-5 injury equivalent (0.10). The results are shown in the lower right portion of Table VIII-9.

In Table VIII-10, the discounted annual nonfatal injuries from Table VIII-8 were multiplied by the factors shown in the lower right of Table VIII-9 to produce estimates of the total discounted fatal equivalents represented by nonfatal injuries. In Table VIII-11, these fatal equivalents are added to the discounted annual fatalities prevented from Table VIII-6 to produce the total fatal equivalents

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[1]Blincoe, L.J., The Economic Cost of Motor Vehicle Crashes, 1994, Washington D.C., DOT HS 808 425, July 1996

from both fatalities and injuries. The results indicate systems designed to Alternative 1 requirements could save up to 316 equivalent fatalities, but could also prevent up to 24 <u>fewer</u> equivalent fatalities than the pre-MY 1998 requirements. Systems designed to the Alternative 2 requirements could save from 168 to 342 fatal equivalents. Advanced air bag systems designed to Alternative 3 requirements could save up to 356 equivalent fatalities, but could also prevent up to 5 <u>fewer</u> equivalent fatalities than the pre-MY 1998 requirements.

In Table VIII-12, the total annual costs from Table VIII-4 are divided by the discounted fatal equivalents from Table of VIII-11 to produce estimates of the net cost (or savings) per fatality saved (CPF) for each compliance option. In cases where there are both positive costs and safety benefits, a net cost per fatal equivalent is appropriate. However, in some cases, there is a net cost benefit due to property damage savings, or a negative safety impact. In these cases, CPF calculations are not appropriate because there is no actual net cost or benefit.

The results indicate that Alternative 1 could produce a net cost per equivalent fatality of from $1.9 million to $30.9 million. However, under Option 1, it could also fail to produce added safety benefits compared to the baseline fleet, with a loss of 24 equivalent fatalities and a net cost of $129 million. Under Option 2, it could result in a net cost savings of $303 million and a reduction of 313 equivalent fatalities.

For Alternative 2, CPF could range from $770,000 to $1.8 million. However, under Option 2 it could result in both a net cost savings of $303 million and a savings of 339 equivalent fatalities. Alternative 3 could produce a net cost per equivalent fatality of $1.9 to $9.0 million. However, under Option 1, it could also fail to produce added safety benefits compared to the baseline fleet, with a loss of 5 equivalent fatalities and a net cost of $170 million. Under Option 2, it could result in a net cost savings of $254 million and a reduction of 353 equivalent fatalities.

Following is an example of the calculations that produced the estimate for the low end costs for Alternative 2, Compliance Option #2:

$24.10	compliance cost (Table VIII-1)
- $12.15	property damage savings (Table VIII-2)
$11.95	net cost (Table VIII-3)
x 15.5	million vehicles
$185.2	million (Table VIII-4)

204	lives saved (Table VIII-5)
x 0.7215	(discounted to present value using a 7% discount rate)
147	lives saved (Table VIII-6)

861	nonfatal injuries prevented (Table VIII-7)
x 0.7215	(discounted to present value using a 7% discount rate)
621	nonfatal injuries prevented (Table VIII-8)

Passengers:
509 nonfatal injuries prevented (Table VIII-8) x .1376 factor (Table VIII-9) = 70.0 fatal equivalents.

Drivers:
112 nonfatal injuries prevented (Table VIII-8) x .1192 factor (Table VIII-9) = 13.4 fatal equivalents.

Total fatal equivalents = 147 fatalities + 70.0 nonfatal passengers +13.4 nonfatal drivers = 230 (Table VIII-11)

$185.2 million/230 = $801,840 per equivalent life saved (Table VIII-12)

Note that systems for drivers appear to be far less cost-effective than those for passengers, primarily because the potential safety problem for drivers is small, and because passenger-side systems have potential for property damage savings.

Table VIII-1
Compliance Cost

		Passenger		Driver		Combined	
Ref. #	TEST -SYSTEMS	Low	High	Low	High	Low	High
1	Suppression w/ Child Presence						
a	-Weight Sensor	$20.50	$24.45				
b	-Presence Sensor	$41.15	$60.90				
2	Low Risk Deployment						
a	- modified fold patterns/inflators	NA	NA	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflators	$3.60	$21.15	$1.50	$19.65	$5.10	$40.80
3	30 mph, Unbelted, 5th female						
a	- modified fold patterns/inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflator	$3.60	$21.15	$1.50	$19.65	$5.10	$39.10
4	25 mph Offset Barrier, Belted, 5th female						
a	- added sensors	$0.00	$7.15	$0.00	$7.15	$0.00	$14.30
b	- Multi-stage inflators	$3.60	$21.15	$1.50	$19.65	$5.10	$40.80
5	25 mph Unblted, 5th fem, 50th male						
a	- modified fold patterns/inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflator	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
6	30 mph Bltd&Unbltd (baseline), 50th male						
a	-modified fold patterns	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
7	35 mph Belted 50th Male						
a	-pretensioners	$1.50	$1.80	$1.10	$1.35	$2.60	$3.15
8	30 mph, Belted, 5th female						
a	- modified fold patterns/inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
COMPLIANCE SCENARIOS:*							
	ALT#1, Compliance Option #1	$20.50	$104.75	$0.00	$19.65	$20.50	$124.40
4,5,6,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	$24.10	$45.60	$0.00	$19.65	$24.10	$65.25
4,5,6,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Infant						
	ALT#2, Compliance Option #1	$20.50	$104.75	$0.00	$19.65	$20.50	$124.40
3,4,6,8	Offset and Frontal Barrier Tests	1a+3a+	1a+1b+3b**	2a+3a	2b+3b		
2	Low Risk Deployment - Driver	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	$24.10	$45.60	$0.00	$19.65	$24.10	$65.25
3,4,6,8	Offset and Frontal Barrier Tests	1a+2b+3a	1a+2b+3b	2a+3a	2b+3b		
2	Low Risk Depl. - Driver & Pass.	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Infant						
	ALT#3, Compliance Option #1	$22.00	$106.55	$1.10	$21.00	$23.10	$127.55
4,5,7,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+6a+7a	+5b+6a+7a***	+5a+6a+7a	+5b+6a+7a***		
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	$25.60	$47.40	$1.10	$21.00	$26.70	$68.40
4,5,7,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Infant						

* High and Low estimates represent maximum range of costs.

** $1.75 deducted to reflect double counting of suppression ability and telltale light in weight and proximity sensors.

*** Multi-stage inflators provide compliance for two tests. Therefore only a single system is counted. Also, multi-stage inflators in 2b, 3b, 4b, and 5b include sensor systems in 3a and 4a. Sensor costs are only counted once, but structure is not deducted when its included in sensor costs.

Table VIII-2
Present Discounted Value of Property Damage Saving (7% RATE)

		Passenger		Driver		Combined	
Ref. #	TEST -SYSTEMS	Low	High	Low	High	Low	High
1	Suppression w/ Child Presence						
a	-Weight Sensor	$12.15	$84.80				
b	-Presence Sensor	$12.15	$84.80				
2	Low Risk Deployment						
a	- modified fold patterns/inflators	NA	NA	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
3	30 mph, Unbelted, 5th female						
a	- modified fold patterns/inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflator	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
4	25 mph Offset Barrier, Belted, 5th female						
a	- added sensors	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
5	25 mph Unblted, 5th fem, 50th male						
a	- modified fold patterns/inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflator	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
6	30 mph Bltd&Unbltd (baseline), 50th male						
a	-modified fold patterns	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
7	35 mph Belted 50th Male						
a	-pretensioners	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
8	30 mph, Belted, 5th female						
a	- modified fold patterns/inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	COMPLIANCE SCENARIOS:*						
	ALT#1, Compliance Option #1	$12.15	$84.80	$0.00	$0.00	$12.15	$84.80
4,5,6,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	$12.15	$84.80	$0.00	$0.00	$12.15	$84.80
4,5,6,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Infant						
	ALT#2, Compliance Option #1	$12.15	$84.80	$0.00	$0.00	$12.15	$84.80
3,4,6,8	Offset and Frontal Barrier Tests	1a+3a+	1a+1b+3b**	2a+3a	2b+3b		
2	Low Risk Deployment - Driver	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	$12.15	$84.80	$0.00	$0.00	$12.15	$84.80
3,4,6,8	Offset and Frontal Barrier Tests	1a+2b+3a	1a+2b+3b	2a+3a	2b+3b		
2	Low Risk Depl. - Driver & Pass.	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Infant						
	ALT#3, Compliance Option #1	$12.15	$84.80	$0.00	$0.00	$12.15	$84.80
4,5,7,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	$12.15	$84.80	$0.00	$0.00	$12.15	$84.80
4,5,7,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Infant						

* High and Low estimates represent maximum range of costs.

Table VIII-3
Net Consumer Costs (Savings)

		Passenger		Driver		Combined	
Ref. #	TEST -SYSTEMS	Low	High	Low	High	Low	High
1	Suppression w/ Child Presence						
a	-Weight Sensor	$8.35	($60.35)				
b	-Presence Sensor	$29.00	($23.90)				
2	Low Risk Deployment						
a	- modified fold patterns/inflators	NA	NA	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflators	$3.60	$21.15	$1.50	$19.65	$5.10	$40.80
3	30 mph, Unbelted, 5th female						
a	- modified fold patterns/inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflator	$3.60	$18.95	$1.50	$19.65	$5.10	$40.80
4	25 mph Offset Barrier, Belted, 5th female						
a	- added sensors	$0.00	$7.15	$0.00	$7.15	$0.00	$14.30
b	- Multi-stage inflators	$3.60	$21.15	$1.50	$19.65	$5.10	$40.80
5	25 mph Unblted, 5th fem, 50th male						
a	- modified fold patterns/inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b	- Multi-stage inflator	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
6	30 mph Bltd&Unbltd (baseline), 50th male						
a	-modified fold patterns	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
7	35 mph Belted 50th Male						
a	-pretensioners	$1.50	$1.80	$1.10	$1.35	$2.60	$3.15
8	30 mph, Belted, 5th female						
a	- modified fold patterns/inflators	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	COMPLIANCE SCENARIOS:*						
	ALT#1, Compliance Option #1	$8.35	$19.95	$0.00	$19.65	$8.35	$39.60
4,5,6,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	$11.95	($39.20)	$0.00	$19.65	$11.95	($19.55)
4,5,6,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Infant						
	ALT#2, Compliance Option #1	$8.35	$19.95	$0.00	$19.65	$8.35	$39.60
3,4,6,8	Offset and Frontal Barrier Tests	1a+3a+	1a+1b+3b**	2a+3a	2b+3b		
2	Low Risk Deployment - Driver	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	$11.95	($39.20)	$0.00	$19.65	$11.95	($19.55)
3,4,6,8	Offset and Frontal Barrier Tests	1a+2b+3a	1a+2b+3b	2a+3a	2b+3b		
2	Low Risk Depl. - Driver & Pass.	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Infant						
	ALT#3, Compliance Option #1	$9.85	$21.75	$1.10	$21.00	$10.95	$42.75
4,5,7,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	$13.45	($37.40)	$1.10	$21.00	$14.55	($16.40)
4,5,7,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Infant						

* High and Low estimates represent maximum range of costs.

Table VIII-4
Total Present Discounted Value of Consumer Costs (Savings) (7% RATE)

		Passenger		Driver		Combined	
Ref. #	Test Systems	Low	High	Low	High	Low	High
1	Suppression w/ Child Presence						
a	-Weight Sensor	$129,425,000	($935,425,000)				
b	-Presence Sensor	$449,500,000	($370,450,000)				
2	Low Risk Deployment						
a	- modified fold patterns/inflators	NA	NA	$0	$0	$0	$0
b	- Multi-stage inflators	$55,800,000	$327,825,000	$23,250,000	$304,575,000	$79,050,000	$632,400,000
3	30 mph, 5th female, Blt. &Unblt.						
a	- modified fold patterns/inflators	$0	$0	$0	$0	$0	$0
b	- Multi-stage inflator	$55,800,000	$327,825,000	$23,250,000	$304,575,000	$79,050,000	$632,400,000
4	25 mph Offset Barrier Test						
a	- added sensors	$0	$110,825,000	$0	$110,825,000	$0	$221,650,000
b	- Multi-stage inflators	$55,800,000	$327,825,000	$23,250,000	$304,575,000	$79,050,000	$632,400,000
5	25 mph Unblted, 5th fem, 50th male						
a	- modified fold patterns/inflators	$0	$0	$0	$0	$0	$0
b	- Multi-stage inflator	$0	$0	$0	$0	$0	$0
6	Frontal Barrier Test, 50th male						
a	-modified fold patterns	$0	$0	$0	$0	$0	$0
7	35 mph Belted 50th Male						
a	-pretensioners	$23,250,000	$27,900,000	$17,050,000	$20,925,000	$40,300,000	$48,825,000
8	30 mph, Belted, 5th female						
a	-modified fold patterns/inflators	$0	$0	$0	$0	$0	$0
	COMPLIANCE SCENARIOS:*						
	ALT#1, Compliance Option #1	$129,425,000	$309,225,000	$0	$304,575,000	$129,425,000	$613,800,000
4,5,6,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	$185,225,000	($607,600,000)	$0	$304,575,000	$185,225,000	($303,025,000)
4,5,6,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Infant						
	ALT#2, Compliance Option #1	$129,425,000	$309,225,000	$0	$304,575,000	$129,425,000	$613,800,000
3,4,6,8	Offset and Frontal Barrier Tests	1a+3a+	1a+1b+3b**	2a+3a	2b+3b		
2	Low Risk Deployment - Driver	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	$185,225,000	($607,600,000)	$0	$304,575,000	$185,225,000	($303,025,000)
3,4,6,8	Offset and Frontal Barrier Tests	1a+2b+3a	1a+2b+3b	2a+3a	2b+3b		
2	Low Risk Depl. - Driver & Pass.	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Passengers						
	ALT#3, Compliance Option #1	$152,675,000	($337,125,000)	$17,050,000	$325,500,000	$169,725,000	($662,625,000)
4,5,7,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+a7+8a***		
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	$208,475,000	($579,700,000)	$17,050,000	$325,500,000	$225,525,000	($254,200,000)
4,5,7,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+a7+8a***		
1	Suppression - Passengers						

*High and Low estimates represent maximum range of costs.

Table VIII-5
Lives Saved

		Passenger		Driver		Combined	
Ref. #	TEST -SYSTEMS	Low	High	Low	High	Low	High
1	Suppression w/ Child Presence						
a	-Weight Sensor	93	93				
b	-Presence Sensor	93	122				
2	Low Risk Deployment						
a	- modified fold patterns/inflators	NA	NA	24	24	24	24
b	- Multi-stage inflators	137	137	40	40	177	177
3	30 mph, 5th female, Blt. &Unblt.						
a	- modified fold patterns/inflators	10	10	9	9	19	19
b	- Multi-stage inflator	147	147	49	49	196	196
4	25 mph Offset Barrier Test						
a	- added sensors	4	12	36	36	40	48
b	- Multi-stage inflators	139	147	58	58	197	205
5	25 mph Unblted, 5th fem, 50th male						
a	- modified fold patterns/inflators	-72	0	-278	0	-350	0
b	- Multi-stage inflator	52	137	-269	40	-217	177
6	Frontal Barrier Test, 50th male						
a	-modified fold patterns	0	0	0	0	0	0
7	35 mph Belted 50th Male						
a	pretensioners	0	1	0	3	0	4
8	30 mph, Belted, 5th female						
a	modified fold patterns/inflators	0	0	4	4	4	4
	COMPLIANCE SCENARIOS:*						
	ALT#1, Compliance Option #1	23	149	-256	62	-233	211
4,5,6	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	54	147	-256	62	-202	209
4,5,6	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Infant						
	ALT#2, Compliance Option #1	107	159	55	71	162	230
3,4,6	Offset and Frontal Barrier Tests	1a+3a+	1a+1b+3b**	2a+3a	2b+3b		
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	149	157	55	71	204	228
3,4,6	Offset and Frontal Barrier Tests	1a+2b+3a	1a+2b+3b	2a+3a	2b+3b		
2	Low Risk Depl. - Driver & Pass.	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Infant						
	ALT#3, Compliance Option #1	23	150	-256	65	-233	215
4,5,7,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	54	148	-256	65	-202	213
4,5,7,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Infant						

*High and Low estimates represent maximum range of costs.

Table VIII-6
Present Discounted Value of Lives Saved (7% RATED)

		Passenger		Driver		Combined	
Ref. #	TEST -SYSTEMS	Low	High	Low	High	Low	High
1	Suppression w/ Child Presence						
a	-Weight Sensor	67	67				
b	-Presence Sensor	67	88				
2	Low Risk Deployment						
a	- modified fold patterns/inflators	NA	NA	17	17	17	17
b	- Multi-stage inflators	99	99	29	29	128	128
3	30 mph, Unbelted, 5th female						
a	- modified fold patterns/inflators	7	7	6	6	14	14
b	- Multi-stage inflator	106	106	35	35	141	141
4	25 mph Offset Barrier, Belted, 5th female						
a	- added sensors	3	9	26	26	29	35
b	- Multi-stage inflators	100	106	42	42	142	148
5	25 mph Unblted, 5th fem, 50th male						
a	- modified fold patterns/inflators	-52	0	-201	0	-253	0
b	- Multi-stage inflator	38	99	-194	29	-157	128
6	30 mph Bltd&Unbltd (baseline), 50th male						
a	-modified fold patterns	0	0	0	0	0	0
7	35 mph Belted 50th Male						
a	-pretensioners	0	1	0	2	0	3
8	30 mph, Belted, 5th female						
a	- modified fold patterns/inflators	0	0	3	3	3	3
	COMPLIANCE SCENARIOS:*						
	ALT#1, Compliance Option #1	17	108	-185	45	-168	152
4,5,6,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	39	106	-185	45	-146	151
4,5,6,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Infant						
	ALT#2, Compliance Option #1	77	115	40	51	117	166
3,4,6,8	Offset and Frontal Barrier Tests	1a+3a+	1a+1b+3b**	2a+3a	2b+3b		
2	Low Risk Deployment - Driver	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	108	113	40	51	147	165
3,4,6,8	Offset and Frontal Barrier Tests	1a+2b+3a	1a+2b+3b	2a+3a	2b+3b		
2	Low Risk Depl. - Driver & Pass.	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
	ALT#3, Compliance Option #1	17	108	-185	47	-168	155
4,5,7,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	39	107	-185	47	-146	154
4,5,7,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Infant						

*High and Low estimates represent maximum range of costs.

Table VIII-7
Nonfatal Injuries Prevented

		Passenger		Driver		Combined	
Ref. #	TEST -SYSTEMS	Low	High	Low	High	Low	High
1	Suppression w/ Child Presence						
a	-Weight Sensor	151	151				
b	-Presence Sensor	151	206				
2	Low Risk Deployment						
a	- modified fold patterns/inflators	NA	NA	20	20	20	20
b	- Multi-stage inflators	517	517	1069	1069	1586	1586
3	30 mph, Unbelted, 5th female						
a	- modified fold patterns/inflators	71	71	70	70	141	141
b	- Multi-stage inflator	588	588	1139	1139	1727	1727
4	25 mph Offset Barrier, Belted, 5th female						
a	- added sensors	101	229	54	54	155	283
b	- Multi-stage inflators	615	743	1105	1105	1720	1848
5	25 mph Unblted, 5th fem, 50th male						
a	- modified fold patterns/inflators	320	320	1062	1062	1382	1382
b	- Multi-stage inflator	517	517	1069	1069	1586	1586
6	30 mph Bltd&Unbltd (baseline), 50th male						
a	-modified fold patterns	6	16	0	0	6	16
7	35 mph Belted 50th Male						
a	-pretensioners	43	94	213	392	256	486
8	30 mph, Belted, 5th female						
a	- modified fold patterns/inflators	14	14	29	29	43	43
	COMPLIANCE SCENARIOS:*						
	ALT#1, Compliance Option #1	583	768	1127	1134	1710	1902
4,5,6,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	629	757	1127	1134	1756	1891
4,5,6,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Infant						
	ALT#2, Compliance Option #1	343	855	155	1204	498	2059
3,4,6,8	Offset and Frontal Barrier Tests	1a+3a+	1a+1b+3b**	2a+3a	2b+3b		
2	Low Risk Deployment - Driver	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	706	844	155	1204	861	2048
3,4,6,8	Offset and Frontal Barrier Tests	1a+2b+3a	1a+2b+3b	2a+3a	2b+3b		
2	Low Risk Depl. - Driver & Pass.	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Infant						
	ALT#3, Compliance Option #1	626	862	1340	1526	1966	2388
4,5,7,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	672	851	1340	1526	2012	2377
4,5,7,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Infant						

*High and Low estimates represent maximum range of costs.

Table VIII-8
Percent Discounted Value of Nonfatal Injuries Prevented (7%RATE)

		Passenger		Driver		Combined	
Ref. #	TEST -SYSTEMS	Low	High	Low	High	Low	High
1	Suppression w/ Child Presence						
a	-Weight Sensor	109	109				
b	-Presence Sensor	109	149				
2	Low Risk Deployment						
a	- modified fold patterns/inflators	NA	NA	14	14	14	14
b	- Multi-stage inflators	373	373	771	771	1144	1144
3	30 mph, Unbelted, 5th female						
a	- modified fold patterns/inflators	51	51	51	51	102	102
b	- Multi-stage inflator	424	424	822	822	1246	1246
4	25 mph Offset Barrier, Belted, 5th female						
a	- added sensors	73	165	39	39	112	204
b	- Multi-stage inflators	444	536	797	797	1241	1333
5	25 mph Unblted, 5th fem, 50th male						
a	- modified fold patterns/inflators	231	231	766	766	997	997
b	- Multi-stage inflator	373	373	771	771	1144	1144
6	30 mph Bltd&Unbltd (baseline), 50th male						
a	-modified fold patterns	4	12	0	0	4	12
7	35 mph Belted 50th Male						
a	-pretensioners	31	68	154	283	185	351
8	30 mph, Belted, 5th female						
a	- modified fold patterns/inflators	10	10	21	21	31	31
	COMPLIANCE SCENARIOS:*						
	ALT#1, Compliance Option #1	421	554	813	818	1234	1372
4,5,6,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	454	546	813	818	1267	1364
4,5,6,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+6a+8a	+5b+6a+8a***	+5a+6a+8a	+5b+6a+8a***		
1	Suppression - Infant						
	ALT#2, Compliance Option #1	247	617	112	869	359	1486
3,4,6,8	Offset and Frontal Barrier Tests	1a+3a+	1a+1b+3b**	2a+3a	2b+3b		
2	Low Risk Deployment - Driver	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Passengers						
	ALT#2, *Compliance* Option #2	509	609	112	869	621	1478
3,4,6,8	Offset and Frontal Barrier Tests	1a+2b+3a	1a+2b+3b	2a+3a	2b+3b		
2	Low Risk Depl. - Driver & Pass.	+4a+6a+8a***	+4b+6a+8a***	+4a+6a+8a	+4b+6a+8a***		
1	Suppression - Infant						
	ALT#3, Compliance Option #1	452	622	967	1101	1419	1723
4,5,7,8	Offset and Frontal Barrier Tests	1a+4a	1a+1b+4b**	2a+4a	2b+4b		
2	Low Risk Deployment - Driver	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	485	614	967	1101	1452	1715
4,5,7,8	Offset and Frontal Barrier Tests	1a+2b+4a	1a+2b+4b	2a+4a	2b+4b		
2	Low Risk Depl. - Driver & Pass.	+5a+7a+8a	+5b+7a+8a***	+5a+7a+8a	+5b+7a+8a***		
1	Suppression - Infant						

*High and Low estimates represent maximum range of costs.

Table VIII-9
Calculation of Cost Per Equivalent
Fataltiy and Weighted Fatal Equivalents

Injury Severity	Comp. Value	Property Damage	Travel Delay	Revised Comp. Value	Relative	1994 PR Incidence	MAIS 2-5 Distribution	MAIS 3-5 Distribution	MAIS 2-5/ Fatality	MAIS 3-5/ Fatality
MAIS1	10840	3263	203	7374	0.0026					
MAIS2	133700	3356	203	130141	0.0457	335465	65.09%		0.03	
MAIS3	472290	5771	203	466316	0.1639	155961	30.26%	86.70%	0.05	0.14
MAIS4	1193860	8346	202	1185312	0.4166	17008	3.30%	9.46%	0.01	0.04
MAIS5	2509310	8018	203	2501089	0.8791	6914	1.34%	3.84%	0.01	0.03
Fatal	2854500	9138	453	2844909	1.0000					
						515348	100.00%	100.00%	0.10	0.22
						179883				

	Percent Injuries from At-Risk Group				Average Weighted Fatal Equivalents			
	Passenger		Driver		Passenger		Driver	
	Low	High	Low	High	Low	High	Low	High
Alt 1, Opt 1	27.79%	28.52%	2.31%	2.91%	0.1356	0.1364	0.1075	0.1081
Alt 1, Opt 2	33.23%	27.61%	2.31%	2.91%	0.1416	0.1354	0.1075	0.1081
Alt2, Opt 1	44.90%	25.61%	12.90%	2.74%	0.1545	0.1332	0.1192	0.1080
Alt2, Opt 2	29.60%	24.76%	12.90%	2.74%	0.1376	0.1323	0.1192	0.1080
Alt3, Opt 1	24.28%	25.41%	1.94%	2.16%	0.1317	0.1330	0.1071	0.1073
Alt3, Opt 2	31.10%	24.56%	1.94%	2.16%	0.1393	0.1320	.1071	0.1073

Table III-10
Equivalent Fatalities from Nonfatal Injuries (Discounted @ 7%)

		Passenger		Driver		Combined	
		Low	High	Low	High	Low	High
COMPLIANCE SCENARIOS:*							
	ALT#1, Compliance Option #1	57	76	87	88	144	164
4,5,6,8	Offset and Frontal Barrier Tests						
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	64	74	87	88	152	162
4,5,6,8	Offset and Frontal Barrier Tests						
2	Low Risk Depl. - Driver & Pass.						
1	Suppression - Infant						
	ALT#2, Compliance Option #1	38	82	13	94	52	176
3,4,6,8	Offset and Frontal Barrier Tests						
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	70	81	13	94	83	174
3,4,6,8	Offset and Frontal Barrier Tests						
2	Low Risk Depl. - Driver & Pass.						
1	Suppression - Infant						
	ALT#3, Compliance Option #1	59	83	104	118	163	201
4,5,7,8	Offset and Frontal Barrier Tests						
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	68	81	104	118	171	199
4,5,7,8	Offset and Frontal Barrier Tests						
2	Low Risk Depl. - Driver & Pass.						
1	Suppression - Infant						

Table VIII-11
Total Equivalent Fatalities (Discounted @ 7%)

		Passenger		Driver		Combined	
		Low	High	Low	High	Low	High
COMPLIANCE SCENARIOS:*							
	ALT#1, Compliance Option #1	74	183	-97	133	-24	316
4,5,6,8	Offset and Frontal Barrier Tests						
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	103	180	-97	133	6	313
4,5,6,8	Offset and Frontal Barrier Tests						
2	Low Risk Depl. - Driver & Pass.						
1	Suppression - Infant						
	ALT#2, Compliance Option #1	115	197	53	145	168	342
3,4,6,8	Offset and Frontal Barrier Tests						
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	178	194	53	145	231	339
3,4,6,8	Offset and Frontal Barrier Tests						
2	Low Risk Depl. - Driver & Pass.						
1	Suppression - Infant						
	ALT#3, Compliance Option #1	76	191	-81	165	-5	356
4,5,7,8	Offset and Frontal Barrier Tests						
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	106	188	-81	165	25	353
4,5,7,8	Offset and Frontal Barrier Tests						
2	Low Risk Depl. - Driver & Pass.						
1	Suppression - Infant						

Table VIII-12
Net Cost (Savings) Per Equivalent Fatality Saved

		Passenger		Driver		Combined	
		Low	High	Low	High	Low	High
COMPLIANCE SCENARIOS:*							
	ALT#1, Compliance Option #1	$1,748,986	$1,689,754	$0	$2,290,038	($5,392,706)	$1,942,405
4,5,6,8	Offset and Frontal Barrier Tests					NS	
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#1, Compliance Option #2	$1,798,301	($3,375,556)	$0	$2,290,038	$30,870,387	($968,131)
4,5,6,8	Offset and Frontal Barrier Tests						NC
2	Low Risk Depl. - Driver & Pass.						
1	Suppression - Infant						
	ALT#2, Compliance Option #1	$1,125,435	$1,569,670	$0	$2,100,517	$770,387	$1,794,737
3,4,6,8	Offset and Frontal Barrier Tests						
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#2, Compliance Option #2	$1,040,590	($3,131,959)	$0	$2,100,517	$801,840	($893,879)
3,4,6,8	Offset and Frontal Barrier Tests						NC
2	Low Risk Depl. - Driver & Pass.						
1	Suppression - Infant						
	ALT#3, Compliance Option #1	$2,008,882	$1,765,052	($210,494)	$1,972,727	($33,945,000)	$1,861,306
4,5,7,8	Offset and Frontal Barrier Tests					NS	
2	Low Risk Deployment - Driver						
1	Suppression - Passengers						
	ALT#3, Compliance Option #2	$1,966,745	($3,083,511)	($210,494)	$1,972,727	$9,021,000	($720,113)
4,5,7,8	Offset and Frontal Barrier Tests						NC
2	Low Risk Depl. - Driver & Pass.						
1	Suppression - Infant						

NS = Negative safety benefits
NC = No cost, or a net cost savings

IX. REGULATORY FLEXIBILITY ACT AND UNFUNDED MANDATES REFORM ACT ANALYSIS

A. Regulatory Flexibility Act

The Regulatory Flexibility Act of 1980 (5 U.S.C. §601 et seq.) requires agencies to evaluate the potential effects of their proposed and final rules on small businesses, small organizations and small governmental jurisdictions.

5 U.S.C. §Section 603 requires agencies to prepare and make available for public comment an initial and final regulatory flexibility analysis (RFA) describing the impact of proposed and final rules on small entities. Section 603(b) of the Act specifies the content of a RFA. Each RFA must contain:

1. A description of the reasons why action by the agency is being considered;
2. A succinct statement of the objectives of, and legal basis for, the final rule;
3. A description of and, where feasible, an estimate of the number of small entities to which the final rule will apply;
4. A description of the projected reporting, record keeping and other compliance requirements of a final rule including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record;
5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap or conflict with the final rule.

6. Each final regulatory flexibility analysis shall also contain a description of any significant alternatives to the final rule which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the final rule on small entities.

1. <u>Description of the reasons why action by the agency is being considered</u>

NHTSA is considering this action to preserve and enhance the benefits of air bags for all occupants while eliminating or minimizing the risk of air bag induced injuries.

The sheer number and variety of available technological opportunities creates special challenges from a regulatory perspective. While the availability of multiple technologies provide more opportunity to the current problem with air bags, it also means that the agency must take special care to ensure that the regulatory language it adopts would not be unnecessarily design-restrictive.

While air bags are highly effective in reducing the likelihood of death or serious injury in motor vehicle crashes, the degree of their effectiveness depends upon the correct combination of the air bags' speed and aggressiveness of inflation and the positioning of the occupant at the time of deployment.

2. <u>Objectives of, and legal basis for, the final rule</u>

The final rule requires that motor vehicles be tested to minimize the risk of air bag injury to (a) drivers which end up too close to the air bag and (b) children if placed in the front passenger-side seat.

NHTSA has issued this final rule under the authority of the NHTSA Reauthorization Act of 1998 and 49 U.S.C. 322, 30111, 30115, 30117 and 30166; delegation of authority at 49 CFR 1.50. The agency is authorized to issue Federal motor vehicle safety standards that meet the need for motor vehicle safety.

3. Description and estimate of the number of small entities to which the final rule will apply

The final rule would affect motor vehicle manufacturers, second-stage or final-stage manufacturers, alterers, air bag manufacturers, dummy manufacturers, and manufacturers of seating systems. Business entities are generally defined as small businesses by Standard Industrial Classification (SIC) code, for the purposes of receiving Small Business Administration assistance. One of the criteria for determining size, as stated in 13 CFR 121.201, is the number of employees in the firm. To qualify as a small business in the Motor Vehicles and Passenger Car Bodies (SIC 3711), the firm must have fewer than 1,000 employees. For air bag manufacturers and seating systems suppliers to qualify as a small business in the Motor Vehicle Parts and Accessories category (SIC 3714), the firm must have fewer than 750 employees. Test dummy manufacturers must have fewer than 500 employees to qualify as a small business.

Small vehicle manufacturers

Currently, there are about 4 small motor vehicle manufacturers in the United States. These manufacturers will have difficulty certifying compliance with the tests, just as it is currently hard for them to meet the air bag requirements. Many of these manufacturers have in the past petitioned NHTSA for temporary relief on the air bag rule because of economic hardship. This proposal would add to their difficulties. Much of the air bag work for these small vehicle manufacturers is done by air bag suppliers.

In the SNPRM, NHTSA proposed that manufacturers with production of fewer than 5,000 vehicles per year be able to wait until the end of the phase-in period to meet the new requirements. These small manufacturers typically purchase air bag equipment from suppliers, who are busy supplying larger companies during the phase-in period. The Coalition of Small Volume Automobile Manufacturers (COSVAM) (Docket No. 99-6407-32) supported the proposal for the effective date being at the end of the phase-in period, but suggested that the limit be 10,000 vehicles per year. COSVAM argued that the limit should be based on the overall statutory scheme and not on current production volumes. COSVAM stated that the 1999 production of its member companies ranged from 300 to 4,000 units.

Final stage manufacturers and alterers

There are a significant number (several hundred) of second-stage or final-stage manufacturers and alterers that could be impacted by the final rule. These manufacturers buy incomplete vehicles or add seating systems to vehicles without seats, or take out existing seats and add new seats. Many of these vehicles are van conversions, but there are a variety of vehicles affected. The common thread for these vehicles and most of the problems arise when the seat becomes involved. If an original equipment vehicle manufacturer uses a sensing system in the seat for weight sensing or presence sensing, then the second-stage manufacturer or alterer may need to use seats from the original manufacturer or will have to rely on a supplier to provide the same technology for their seats. If not, then the second-stage manufacturer or alterer may only be able to recover the seat, or they would have to certify compliance in some other way.

The generic sled test has made it easier currently for these manufacturers to certify compliance. The Recreation Vehicle Industry Association (Docket # 99-6407-35) urged NHTSA to continue to allow small volume manufacturers and alterers to certify compliance with FMVSS 208 by means of a generic sled test pulse. The agency realizes that crash testing a number of vehicles is not financially practical for these manufacturers. However, it is up to the manufacturers to determine the best way to assure compliance of their vehicles. Certainly, sled testing is an accepted engineering practice. But it does not test all of the attributes (such as weight sensing or presence sensing) of the countermeasures that may be utilized to meet the final rule. These manufacturers will have a more difficult time and more expense certifying to the final rule with some advanced air bag systems. If they rely on suppliers to provide the same technology, then it involves an additional expense and engineering to get the technology into the seat and probably testing to assure compliance. These costs would have to be passed on to the consumers.

One of their more difficult challenges is getting changed models and the information needed for pass-through certification from the first-stage manufacturer in time to certify vehicles in the beginning of the model year. RVIA requests a one-year extension for compliance after the 100 percent phase-in for regular production. The agency is fulfilling this request to the extent possible. For a discussion of this issue see the leadtime discussion at the end of Chapter VII.

The National Truck Equipment Association (NTEA) provided the following comments (Docket No. 99-6407-31). NTEA has 1,600 member companies throughout the nation, virtually all of them are small businesses. To demonstrate compliance with FMVSS 208, a final stage manufacturer must primarily rely upon the chassis manufacturers certification of compliance. To pass through compliance, the final stage manufacturer must complete the vehicle in accordance with the chassis manufacturers instructions. In some cases, based on market demands and chassis manufacturers instructions, this may not be possible. Additionally, in the case of vehicles completed from incomplete chassis cabs, such as chassis cowls, chassis cutaways, and strip chassis, such a "pass through" is not available under NHTSA certification regulations. NTEA does not believe there is a significant population of vehicles produced from such non-chassis cab incomplete vehicles which are required to meet FMVSS 208 (that would be at 8,500 lbs. GVWR or less and an unloaded vehicle weight of 5,500 pounds or less). As a practical matter, the chassis manufacturers need to do a great deal of work to come up with the compliance information for use by multi-stage manufacturers in order for the pass-through to be available. Typically, the chassis manufacturers leave this work for last. If such information is not available, the small businesses will have no means to provide compliance information. Hence, it is vitally important that the chassis manufacturers be given as much time as possible, and NTEA requests that the phase-in start September 1, 2003 and be fully effective September 1, 2006 as allowed in the NHTSA Reauthorization Act of 1998.

Air bag suppliers

There are about five main suppliers of air bag systems. (TRW, Autoliv, Breed, Takata, Delphi.) None of these suppliers would be considered a small business. There might be some second and third tier manufacturers of components of air bags or of sensors that are small businesses, but the agency does not believe there are a substantial number. These final rules should have a positive effect on the air bag manufacturers and on the second and third tier manufacturers of air bag components.

Test dummy manufacturers

The final rule should have a positive effect on the manufacturers of test dummies and the manufacturers of instrumentation for test dummies. In order to do the required tests, an increased number of dummies would be needed. There are currently four manufacturers of dummies or parts of dummies (First Technology Safety Systems, Advanced Safety Technology Corp., UTAMA, and GESAC). All of these would qualify as small businesses with less than 500 employees. There are four manufacturers of load cells (R.A. Denton, First Technology Safety Systems, Sensor Developments, Inc., and Sensotec) and two manufacturers of accelerometers (Endevco and Entran). All of these manufacturers are believed to be small business except Endevco.

Suppliers of seating systems

In the PEA, NHTSA stated that it knows of 11 suppliers of seating systems, that supply seats to van converters and others, that are small businesses. Depending on the technology chosen to meet the final advanced air bag rule, these suppliers will have to keep up with the technology in order to retain their business.

Bornemann Products Incorporated (Docket 6407 #57and #65) is a small business seating company and provided substantial comments. Their conclusion is that the cost per vehicle and the impact on small business would be devastating, and not just for seating companies. Bornemann estimated the barrier test costs to cover three lines of products for one manufacturer would be at least 12 tests at $62,666 per test for a total of $752,000, assuming no impact simulations and no "failures" in the process. The cost per unit, if Bornemann provided a test program for a collection of customers would be $192 to $294.

Bornemann argued that this rule could have a devastating impact on an entire industry that supplies a "niche" market of custom individuality vehicles. There are about 30 seating companies that supply products in the multi-stage vehicle market with probably $80 million in sales and 2,500 employees. Supplying them are about 130 firms with about 5,000 employees that produce leathers and fabrics, foam products, steel supplies, recliners and seat tracks. In addition, since seats are the most important component of the custom individuality market, if the ability to provide custom seats is taken away, then the whole market for custom individuality vehicles may eliminated and you would have to consider the suppliers of carpets, fabrics, wood, plastics, steel, etc. that provide products to alterers and multi-stage manufacturers of which there are about 550 vendors with 18,000 employees. Bornemann argues that with this rule, you risk eliminating the "niche" light-truck market completely, because it is most likely that the OEM vehicle manufacturers will be reluctant to allow any changes to their chassis, including not only the front seats, but also anything that could impact the air bags and the firing systems. This will reduce the market further than it has been, to virtually nothing as it's known today.

The major alternatives considered for this final rule are whether the high speed rigid barrier test should be at 25 or 30 mph. This does not affect the problems seat manufacturers will have with the new technology added for out-of-position problems, like seat sensors and position sensors. All commenters agree that the agency must reduce the out-of-position problems. Thus, the agency has no choice but to require that all vehicles meet the out-of-position test. Meeting the out-of-position tests cause the biggest problems for small seating companies who supply seats to van conversions etc.

Bornemann estimates the cost of complying with the rigid barrier tests. Again, this testing cost is the same, whichever high speed rigid barrier test is chosen. However, these manufacturers don't necessarily need to do rigid barrier testing. Certainly, sled testing is an accepted engineering practice. But sled testing does not test all of the attributes (such as weight sensing or presence sensing) of the countermeasures that may be utilized to meet the final rule. These manufacturers will have a more difficult time and more expense certifying to the final rule with advanced air bag systems than they have had in the past. However, there products must provide the same level of safety as the original vehicle manufacturers' products. The agency believes these manufacturers will have two choices to comply with the standard. Either:

a) They rely on suppliers to provide the same technology (weight sensing, or whatever) to them as was supplied to the OEM manufacturers, then it involves an additional expense and engineering to get the technology into the seat and possibly static testing to assure compliance with the out-of-position tests if the compliance certification can't be passed on from the supplier. They also have to certify compliance for the rigid barrier test, which possibly could consist of a sled test. These costs would have to be passed on to the consumers. or

b) They purchase the full seat from the OEM manufacturers and recover the seat only, keeping the technology in place. This process was used in the past until information from the original vehicle manufacturers on pass through certification became available and design decisions and testing were made. Similarly, they would have to certify compliance.

Keeping up with technology is not a new problem for these manufacturers. This happens all the time and it will occur more and more as new technology is added to seating systems, including side air bags. The job might not be easy, but they will have to keep up to stay in business. The issue to be addressed by the Regulatory Flexibility Act is whether there are alternatives available that can make compliance easier for small business and not impact safety. The only alternative recommended by commenters was to increase the leadtime for multi-stage manufacturers and alterers. The agency has provided a method for these manufacturers to potentially have one more year of leadtime than the original vehicle manufacturers. That is discussed in the leadtime section.

4. Description of the projected reporting, record keeping and other compliance requirements for small entities

The final rule adopts new performance requirements that would enhance the safety of children and small stature adults. Motor vehicle manufacturers would have to certify that their products comply with the final rule. Manufacturers could use any means to determine that their products comply, so long as they exercise due care in making their certification.

With the phase-in leadtime, manufacturers would be required to report to the agency how they met the phase-in schedule. Reporting of compliance is a small cost, simply requiring clerical skills for its preparation, compared to the flexibility it provides manufacturers in meeting the final rule.

5. Duplication with other Federal rules

There are no relevant Federal rules which may duplicate, overlap or conflict with the final rule.

6. Description of any significant alternatives to the final rule

NHTSA has provided through the final rule phase-in leadtime schedule the only way it could think of to help out these small businesses which would minimize the economic impact of the final rule on small entities. Consistent with the stated objectives, the agency is allowing for a longer lead time for small manufacturers (those with less than 5,000 vehicle sales worldwide) and multi-stage manufacturers and alterers to reduce their burden to the extent possible.

As discussed above, depending upon what technologies are employed and how they affect front seating systems, this final rule could have a significant economic impact on a substantial number of small businesses in the short run. If seating systems are affected by the new technology and if seating suppliers handle this new technology well, they may be able to supply the same technology as used by the original first-stage manufacturers. Thus, the economic impact on the substantial number of small businesses need not be significant in the long run. Leadtime considerations have been made to help these small businesses in the short run.

B. Unfunded Mandates Reform Act

The Unfunded Mandates Reform Act of 1995 (Public Law 104-4) requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditures by State, local or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (adjusted annually for inflation with base year of 1995). The assessment may be included in conjunction with other assessments, as it is here.

This final rule on advance air bags is not likely to result in expenditures by State, local or tribal governments of more than $100 million annually. However, it is estimated to result in the expenditure by automobile manufacturers and/or their suppliers of more than $100 million annually. Since this final rule allows a variety of methods to comply, which have a variety of costs ranging from at least $20 per vehicle for 15.5 million vehicles, it will easily exceed $100 million. The final cost will depend on choices made by the automobile manufacturers.

These effects have been discussed in the Final Economic Assessment, see for example the chapters on Cost, Benefits and the previous discussion in this chapter on the Regulatory Flexibility Act.

X. CUMULATIVE IMPACTS OF RECENT RULEMAKINGS

Section 1(b) II of Executive Order 12866 Regulatory Planning and Review requires the agencies to take into account to the extent practicable "the costs of cumulative regulations". To adhere to this requirement, the agency has decided to examine both the costs and benefits by vehicle type of all substantial final rules with a cost or benefit impact effective from MY 1990 or later. In addition, proposed rules should also be identified and preliminary cost and benefit estimates provided. Besides this rule, in which the costs and benefits are described previously, there are no major outstanding proposals that have quantified costs and benefits.

Costs include primary cost, secondary weight costs and the lifetime discounted fuel costs for both primary and secondary weight. Costs will be presented in two ways, the cost per affected vehicle and the average cost over all vehicles. The cost per affected vehicle includes the range of costs that any vehicle might incur. For example, if two different vehicles need different countermeasures to meet the standard, a range will show the cost for both vehicles. The average cost over all vehicles takes into account voluntary compliance before the rule was promulgated or planned voluntary compliance before the rule was effective and the percent of the fleet for which the rule is applicable. Costs are provided in 1997 dollars, using the implicit GNP deflator to inflate previous estimates to 1997 dollars.

Benefits are provided on an annual basis for the fleet once all vehicles in the fleet meet the rule. Benefit and cost per average vehicle estimates take into account voluntary compliance.

Table X-1

COSTS OF RECENT PASSENGER CAR RULEMAKINGS
(Includes Secondary Weight and Fuel Impacts)
(1997 Dollars)

Description	Effective Model Year	Cost Per Affected Vehicle $	Cost Per Average Vehicle $
FMVSS 114, Key Locking System to Prevent Child-Caused Rollaway	1993	$8.99 - 18.65	$0.50 - 1.03
FMVSS 214, Dynamic Side Impact Test	1994 - 10% phase-in 1995 - 25% 1996 - 40% 1997 - 100%	$65.77 - 640.56	$59.54
FMVSS 208, Locking Latch Plate for Child Restraints	1996	$0.85 - 17.07	$2.29
FMVSS 208, Belt Fit	1998	$3.25 - 16.28	$1.20 - 1.73
FMVSS 208, Air Bags Required	1997 - 95% 1998 - 100	$479.52 - 579.42	$479.52 - 579.42
FMVSS 201, Upper Interior Head Protection	1999 - 10% 2000 - 25% 2001 - 40% 2002 - 70% 2003 - 100%	$35.96	$35.96
FMVSS 225, Child Restraint Anchorage Systems	2001 - 20% 2002 - 50% 2003 - 100%	$2.87 - $6.74	$5.78

Table X-2

BENEFITS OF RECENT PASSENGER CAR RULEMAKINGS
(Annual benefits when all vehicles meet the standard)

Description	Fatalities Prevented	Injuries Reduced	Property Damage Savings $
FMVSS 114, Key Locking System to Prevent Child Caused Rollaway	None	50-99 Injuries	Not Estimated
FMVSS 214, Dynamic Side Impact Test	512	2,626 AIS 2-5	None
FMVSS 208, Locking Latch Plate for Child Restraints	Not estimated	Not estimated	None
FMVSS 208, Air Bags Required Compared to 12.5% Usage in 1983	4,570 - 9,110	AIS 2-5 85,930 - 155,090	None
Compared to 46.1% Usage in 1991	2,842 - 4,505	63,000 - 105,000	
FMVSS 201, Upper Interior Head Protection	575 - 711	251 - 465 AIS 2-5	None
FMVSS 225, Child Restraint Anchorage Systems – Benefits include changes to Child Restraints in FMVSS 213	36 to 50*	1,231 to 2,929*	None

* Total benefits for passenger cars and light trucks

Table X-3
COSTS OF RECENT LIGHT TRUCK RULEMAKINGS
(Includes Secondary Weight and Fuel Impacts)
(1997 Dollars)

Description	Effective Model Year	Cost Per Affected Vehicle $	Cost Per Average Vehicle $
FMVSS 202, Head Restraints	1992	$44.64 - 108.29	$5.28
FMVSS 204, Steering Wheel Rearward Displacement for 4,000 to 5,500 lbs. unloaded	1992	$5.76 - 28.52	$1.02 - 1.93
FMVSS 208, Rear Seat Lap/Shoulder Belts	1992	$65.95	$0.39
FMVSS 114, Key Locking System to Prevent Child-Caused Rollaway	1993	$8.99 - 18.65	$0.01 - 0.03
FMVSS 208, Locking Latch Plate for Child Restraints	1996	$0.85 - 17.07	$2.29
FMVSS 108, Center High-Mounted Stop Lamp	1994	$14.34 - 21.68	$14.79
FMVSS 214, Quasi-Static Test (side door beams)	1994 - 90% 1995 - 100	$64.17 - 80.48	$59.48 - 74.71
FMVSS 216, Roof Crush for 6,000 lbs. GVWR or less	1995	$23.63 - 212.05	$0.85 - 8.40
FMVSS 208, Belt Fit	1998	$3.59 - 16.98	$6.13 - 8.27
FMVSS 208, Air Bags Required	1998 - 90% 1999 - 100	$479.52 - 579.42 dual air bags	$478.52 - 597.42 dual air bags
FMVSS 201, Upper Interior Head Protection	1999 - 10% 2000 - 25% 2002 - 70% 2003 - 100%	$35.62 - 78.00	$54.97
FMVSS 225, Child Restraint Anchorage Systems	2001 - 20% 2002 - 50% 2003 - 100%	$2.87 - $6.74	$5.78

Table X-4

BENEFITS OF RECENT LIGHT TRUCK RULEMAKINGS
(Annual benefits when all vehicles meet the standard)

Description	Fatalities Prevented	Injuries Reduced	Property Damage Savings $
FMVSS 202, Head Restraints	None	470 - 835 AIS 1 20 - 35 AIS 2	None
FMVSS 204, Steering Wheel Rearward Displacement for 4,000 to 5,500 lbs. unloaded	12 - 23	146 - 275 AIS 2-5	None
FMVSS 208, Rear Seat Lap/Shoulder Belts	None	2 AIS 2-5	None
FMVSS 114, Key Locking System to Prevent Child Caused Rollaway	None	1 Injury	Not Estimated
FMVSS 208, Locking Latch Plate for Child Restraint	Not estimated	Not estimated	None
FMVSS 108, Center High Mounted Stop Lamp	None	19,200 to 27,400 Any AIS Level	$119 to 164 Million
FMVSS 214, Quasi-Static Test (side door beams)	58 - 82	1,569 to 1,889 hospitalizations	None
FMVSS 216, Roof Crush for 6,000 lbs. GVWR or less	2 - 5	25-54 AIS 2-5	None
FMVSS 208, Belt Fit	9	102 AIS 2-5	None
FMVSS 208, Air Bags Required Compared to 27.3% Usage in 1991	1,082 - 2,000	21,000 - 29,000 AIS 2-5	None
FMVSS 201, Upper Interior Head Protection	298 - 334	303 - 424	None
FMVSS 225, Child Restraint Anchorage Systems – Benefits include changes to Child Restraints in FMVSS 213	36 to 50*	1,231 to 2,929*	None

* Total benefits for passenger cars and light trucks

APPENDIX A

A. Comparisons of Pre-MY to MY 98/99 Air Bags

Chapter II provided some analysis of MY 98 air bags to pre-MY 98 air bags. In particular, estimates were made using SCI cases that the fatality rate for out-of-position (at-risk) occupants for MY 98 air bags is about 35 percent of the fatality rate for pre-MY 98 air bags. In addition, it was estimated that there was no statistically significant difference in overall fatalities between pre-MY 98 and MY 98 air bags. This appendix provides the Polk data analysis used in Chapter II, and it further analyzes additional real world fatality data and compares pre-MY 98 air bag equipped vehicles to redesigned MY 1998-2000 air bag equipped vehicles. It also examines high speed test data to determine how well the MY 98 and MY 99 air bag vehicles perform compared to pre-MY 98 air bags.

Polk data

Polk has data on the number of registered vehicles. Unfortunately, the latest data available from Polk (July 1, 1998) do not have the total number of MY 1998 vehicles registered, since many MY 1998 vehicles are registered after July 1, 1998. Polk data for July 1, 1997 indicate that there were 13.10 million MY 1996 vehicles registered. Polk data for July 1, 1998 indicate there were 14.17 MY 1997 vehicles registered and 10.05 MY 1998 vehicles registered. Based on the MY 1997 vehicles, the July 1, 1997 Polk data, would have to be multiplied by 1.45 to get an estimate of the total on July 1, 1998. Thus, our best estimate of total registrations for MY 1998, until the July 1, 1999 tables are available, would be 14.57 million vehicles (10.05 x 1.45).[1] (See Table A-1) Note that light truck registrations increased significantly from MY 1996 to MY 1998. All of these vehicles were equipped with frontal air bags for both the driver and right front passenger. An estimated 87 percent of the MY 1998 vehicles had redesigned air bags. Since at this time, each VIN number must be looked up by hand to determine whether it was a redesigned air bag or not, in this analysis, all MY 1998 vehicles are taken together without separating them for redesigned air bags.

Table A-1
Polk Data
(In millions)

	Passenger Cars	**Light Trucks**	**Total**
MY 1996	7.695	5.408	13.103
MY 1997	8.049	6.125	14.174
MY 1998 estimated	8.053	6.516	14.569

[1] Total sales of passenger cars and light trucks in calendar year 1996 and 1997 were essentially the same; 1998 sales were slightly higher. There were 15.14 million sales in 1996, 15.16 million sales in 1997, and 15.55 million sales in 1998. However, calendar year sales do not match model year sales, so the best analysis is to compare fatalities by vehicle model year with registrations by model year. The calendar year data are presented to show that, if anything, the MY 1998 projection of 14.57 million registrations is low and that the fatality rates for MY 98 vehicles shown in the tables might be slightly high.

Analysis of 1998 and the first 6 Months of 1999 FARS Data and Redesigned Air Bags

The agency conducted several analyses using 1998 and the first 6 months of 1999 FARS data to examine the question of how well MY 1998 redesigned air bags are performing.

Fatalities in frontal impacts

An analysis of 1996 to 1998 FARS found essentially the same number of fatalities in frontal impacts for MY 1996 vehicles in 1996 FARS (730), as in MY 1997 vehicles in 1997 FARS (776), as in MY 1998 vehicles in 1998 FARS (732). Passenger car fatalities decreased, while light truck fatalities increased. In addition, frontal impacts were in the range of 48 to 50 percent of fatalities for that group for all three years examined. (See Table A-2)

Table A-2

Fatalities in Frontal Impacts (FARS Data)

	Passenger Cars	Light Trucks	Total
MY96 in FARS 96	448	282	730
MY97 in FARS 97	450	326	776
MY98 in FARS 98	414	318	732

Note: If the number of fatalities were adjusted for belt use increases discussed on Page II-24 between 1996 and 1998, the number of fatalities would be 689 for MY 96 in FARS 96, 753 for MY 97 in FARS 97 and 732 for MY 98 in FARS 98. This would make the fatality rates in Table A-3 be 53 for MY 96 in FARS 96, 53 for MY 97 in FARS 97 and 50 for MY 98 in FARS 98.

Dividing fatalities in frontal impacts by registered vehicles results in Table A-3. Light trucks have lower fatality rates in frontal impacts than passenger cars. Assuming that our estimate of the number of MY 1998 registered vehicles is reasonable, it appears that fatality rates for both passenger cars and light trucks are lower with MY 1998 vehicles than for MY 1997 or MY 1996.

Table A-3

Frontal Fatalities per Million Vehicles Registered

	Passenger Cars	Light Trucks	Total
MY96 in FARS 96	58	52	56
MY97 in FARS 97	56	53	55
MY98 in FARS 98	51	49	50

Calculated for example:

MY 1996 - 730 fatalities/13.10 million vehicles = 56 fatalities per million vehicles

Based on testing with dummies, past agency assessments indicated the possibility that redesigned air bags may not provide full protection for unbelted occupants during high speed impacts. Thus, the same analysis was performed for drivers and right front passengers and for belted and unbelted occupants. The fatality rate appears to have decreased for unbelted right front seat occupants. With one exception, the fatality rate appears to have decreased or remained the same between MY 1996 and MY 1998. The only exception was belted light truck drivers. In order to get a better understanding of the potential reduction in the fatality rate for unbelted right front seat occupants, the fatalities were divided by ages 0-12 and 13 and over. Table A-4 shows a decrease in child deaths from 35 in MY 96 vehicles to 29 in MY 98 vehicles, but it also shows a larger decrease in the number and fatality rate of right front seat occupants of ages 13 and above from 240 deaths in MY 96 vehicles down to 203 deaths in MY 98 vehicles. So, the data indicate the reduction in fatality rates comes mainly from unbelted right front seat occupants age 13 and above. (See Tables A-4 and A-5)

Driver Fatalities in Frontal Impacts by Weight and Height of the Driver

Dummy crash test data tend to indicate that redesigned air bags may not be as effective as pre-redesigned air bags in higher speed crashes. The analysis was performed to investigate the theory that redesigned air bags may not have enough power for heavier and taller occupants. Dummy crash test data to date indicate the worst case would be an unrestrained heavier right front passenger, and that the difference for drivers and restrained right front passengers would be minimal. Unfortunately, data on right front passengers by height and weight are not available on FARS. The 1998 FARS data, for the first time, have been linked to State driver license data, allowing the agency to get weight and height of drivers. MY 1998, 1999, and a few MY 2000 vehicles were decoded using the VIN data to determine whether the vehicles had redesigned air bags or not. Thus, an analysis was performed using 1998 and the first 6 months of 1999 FARS data and comparing MY 1995, 1996, and 1997 vehicles before redesign to the redesigned MY 1998, 1999, and a few 2000 vehicles in the file.

Table A-4
Fatalities and Rates* in Frontal Impacts (FARS Data)

	Passenger Cars		Light Trucks		Passenger Cars & Light Trucks		
	Belted	Unbelted	Belted	Unbelted	Belted	Unbelted	Total
Drivers							
MY96 in FARS 96	148 (19)	139 (18)	58 (11)	110 (20)	206 (16)	249 (19)	455 (35)
MY97 in FARS 97	156 (19)	144 (18)	78 (13)	139 (23)	234 (17)	283 (20)	517 (36)
MY98 in FARS 98	138 (17)	133 (17)	89 (14)	140 (21)	227 (16)	273 (19)	500 (34)
Front-Outboard Passengers							
MY96 in FARS 96	61 (8)	100 (13)	39 (7)	75 (14)	100 (8)	175 (13)	275 (21)
MY97 in FARS 97	63 (8)	87 (11)	40 (7)	69 (11)	103 (7)	156 (11)	259 (18)
MY98 in FARS 98	63 (8)	80 (10)	38 (6)	51 (8)	101 (7)	131 (9)	232 (16)
Total							
MY96 in FARS 96	209 (27)	239 (31)	97 (18)	185 (34)	306 (23)	424 (32)	730 (56)
MY97 in FARS 97	219 (27)	231 (29)	118 (19)	208 (34)	337 (24)	439 (31)	776 (55)
MY98 in FARS 98	201 (25)	213 (26)	127 (19)	191 (29)	328 (23)	404 (28)	732 (50)

* Rate (parenthetical values): fatalities per million registered vehicles.
Note: Due to rounding, the sum of fatality rates for belted and unbelted columns, or drivers and passengers, might not be equal to that in the "Total" column. .

Table A-5
Front-Outboard Passenger Fatalities and Rates* in Frontal Impacts (FARS Data)

	Passenger Cars		Light Trucks		Passenger Cars & Light Trucks		
	Belted	**Unbelted**	**Belted**	**Unbelted**	**Belted**	**Unbelted**	**Total**
Child Passengers (Age 0-12)							
MY96 in FARS 96	10 (1)	12 (2)	5 (1)	8 (1)	15 (1)	20 (2)	35 (3)
MY97 in FARS 97	7 (1)	13 (2)	5 (1)	6 (1)	12 (1)	19 (1)	31 (2)
MY98 in FARS 98	10 (1)	10 (1)	3 (0)	6 (1)	13 (1)	16 (1)	29 (2)
Adult Passengers (Age 13 and Older)							
MY96 in FARS 96	51 (7)	88 (11)	34 (6)	67 (12)	85 (6)	155 (12)	240 (18)
MY97 in FARS 97	56 (7)	74 (9)	36 (6)	62 (10)	92 (6)	136 (10)	228 (16)
MY98 in FARS 98	53 (7)	70 (9)	35 (5)	45 (7)	88 (6)	115 (8)	203 (14)

* Rate (parenthetical values): fatalities per million registered vehicles.

Table A-6 shows the effectiveness of air bags by weight data (in pounds) for all drivers, belted and unbelted. Effectiveness was determined by comparing frontal fatalities to non-frontal fatalities of redesigned air bags to those that were not redesigned. The results are different than anticipated. We would have expected the redesigned air bags to be more effective for the lightest group, that probably sits closest to the steering column and the least effective for the heaviest group, that the redesigned air bags might not have enough power for. However, the differences are <u>not</u> statistically significant.

Table A-6
Effectiveness of Air Bags for Driver Fatalities by Weight
Comparing Redesigned vs. Not Redesigned
Based on FARS 1998 and the first Six Months of FARS 1999

	<=125 lbs.	**126 - 175 lbs.**	**176 - 200 lbs.**	**201 + lbs**	**Total**
Number of frontal fatalities with redesigned	78	278	125	98	579 With Known weight
Effectiveness of redesigned vs. Not redesigned	- 32%	6%	17%	- 4%	

A similar analysis was performed with driver height. The shorter drivers (5'4" and less) and taller drivers (6'1" and more) had a lower effectiveness with the redesigned air bag, however, this analysis found no statistically significant difference by driver height. (See Table A-7)

Table A-7
Driver Fatalities by Driver Height
Based on FARS 1998

	<= 64 inches	**65 - 72 inches**	**73+ inches**	**Total**
Number of frontal fatalities with redesigned	132	520	124	776 With Known Height
Effectiveness of redesigned vs. Not redesigned	- 19%	1%	- 6%	

Analysis of MY 98/99 redesigned air bags and chest g's

Chapter IV provides a variety of test data and analysis of redesigned air bags. In past NHTSA analyses,[2] test data were used to project the potential lives saved or not saved by redesigned air bags compared to pre-MY 1998 air bags. The agency focused on chest g's in these analyses, since the biggest impact appeared to be on chest g's, notably the unrestrained passenger chest g's, and since previous agency evaluations showed that chest g's related well to overall injury. This section updates those analyses using the latest information.

Vehicle Tests

As shown in Chapter IV, matched pair analysis of belted occupants indicate there is little difference in test scores between the pre-MY 1998 and redesigned MY 98/99 air bags. The agency has 6 unbelted 30 mph vehicle matched pair tests of MY 1998 and pre-MY 1998 air bags and 6 additional vehicle matched pair tests of MY 1999 and pre-MY 1998 air bags. These data can be analyzed in different ways depending on the philosophy used. Taking just simple averages of the 6 vehicles' chest g's for matched pairs, as shown in Table A-8, results in the following (60 g's is the injury criteria performance limit):

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[2] "Final Regulatory Evaluation, Actions to Reduce the Adverse Effects of Air Bags, FMVSS No. 208, Depowering", NHTSA, February 1997, (see pages IV-13 and IV-37) and "Preliminary Economic Assessment, FMVSS No. 208, Advanced Air Bags", NHTSA, August 1998 (Docket #98-4405-#2) (see pages VIII-5 to VIII-8)

Table A-8
Comparison of pre-MY 98 to MY 98/99 Vehicles
Chest g's based on 50th Percentile Male Dummy

	PRE MY 1998	MY 1998	MY 1999	Difference
Driver	47.9 g's	45.2 g's		Down 2.7 g's
Driver	41.9 g's		48.3 g's	Up 6.4 g's
Passenger	43.8 g's	48.6 g's		Up 4.8 g's
Passenger	45.6 g's		46.1 g's	Up 0.5 g's

Source: Tables A-11a to A-11d but excluding one confidential MMY

One could look at these data and decide that there isn't much difference between them. Average driver chest g's were slightly down for the 6 MY 98 vehicles, but up considerably for the 6 MY 99 vehicles. Average passenger chest g's were up considerably for the 6 MY 98 vehicles, but were up only slightly for the 6 MY 99 vehicles. Averaging the 12 MY 98 and MY 99 vehicles, under the assumption that they are all redesigned air bag vehicles, results in the driver chest g's being up an insignificant 1.66 chest g's and passenger chest g's being up 2.84 g's on average. One could argue that there is really no significant difference between the two types of air bags.

On the other hand, one could argue that theoretically even a 1 g difference in chest g's is important for safety and you could calculate this impact on safety. Under this philosophy, these same data were analyzed model by model to determine the impact on fatalities using Method 2 from the February 1997 Depowering analysis. The results for the driver were almost exactly the same. The average impact on driver fatalities, after considering each model separately and averaging them was a 1.72 percent increase in fatalities.[3] Thus, the data show no significant difference in unbelted 48 kmph (30 mph) test data for the driver side comparing pre-MY 98 air bags to redesigned MY 98 and MY 99 air bags. The same analysis for the passenger side indicated an average increase in fatalities of 3.5 percent for redesigned MY 98 and MY 99 air bags compared to matched pre-MY 98 air bags.

Based on the two different methodologies used in the 1997 Depowering analysis, the average 2.84 chest g's increase for the passenger side would result in an estimated 9 to 26 lives not saved (under Method 1)[4] and 49 lives that would not be saved (under Method 2)[5] by MY 98/99 air bags compared to pre-MY 98 air bags.

Sled Tests

The agency also performed a group of sled tests using the 95th percentile male dummy to determine whether the MY 98/99 redesigned air bags performed as well as the pre-MY 98 air bags. Table A-9 presents the chest g's data from these tests at 30 and 40 mph. Two sled bucks were used representing a Chevrolet Venture minivan and a Buick Century, equipped with either

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[3] Method 2 employed Table IV-14 (Page IV-35) from the report "Actions to Reduce the Adverse Effects of Air Bags, FMVSS No. 208, Depowering, February, 1997." The percentage change (+/-) in driver-side chest g's for each make/model was computed using 48 g's as the denominator. Table IV-14 was used to compute the changes (+/-) in fatality percentage. The net difference in fatality percentages across the pre-MY98 models and the MY98+99 models was obtained and computed.

[4] (Model 1) 2.84 g's x .96 to 2.80 = 2.73 to 7.952%
.66 x 1.0273 to 1.0795 = .678 to .7125, [(.678 to .7125) - .66] = .018 to .0525
unbelted passenger fatals in the 31 to 40 cell = 502, 502 x [.018 to .0525] = 9 to 26

[5] (Model 2) Unbelted passenger fatals in the 0-40 mph cells = 1,405
1,405 x .035 = 49

MY 1997 or MY 1999 redesigned air bags. Table A-9 presents these data for the driver and right front passenger. While there is one large increase (almost 10 g's) in chest g's for the Buick Century passenger at 30 mph, the rest of the data taken together show no real change in chest g's between the MY 97 and MY 99 redesigned air bags.

However, the agency did find a difference in HIC when the test speed was increased to 45 mph on the sled. While chest g's went down with the redesigned MY 99 air bag, HIC went up dramatically from 904 in the MY 97 Century to 1,731 (the initial impact to the windshield resulted in a HIC of 1,538; upon rebound into the B-pillar the HIC was 1,731) in the MY 99 Century at 45 mph. An analysis of the film from these tests found in both cases the 95[th] percentile male dummy hit the windshield, but the severity of impact was higher with the redesigned air bag. Based on these two vehicles, one could argue that the redesigned air bags are doing a good job up to around 45 mph. Given the data available to date, there appears to be little difference between the pre-MY 98 air bags and the MY 98/99 air bags in terms of high speed crashes up to 40 mph. With 45 mph delta V sled tests, the Buick Century driver chest g's decreased by 9.2 g's and the passenger chest g's increased 0.70 g's compared to a 40 mph delta V.

Table A-9
Driver & Passenger Sled Test Data with 95th Percentile Dummies
(Chest g's)

Speed/Model Year	Chevy Venture - Driver	Buick Century - Driver	Chevy Venture - Passenger	Buick Century - Passenger
30 mph				
MY 97	32.9	45.6	36.7	40.6
MY99	36.0	44.3	33.7	50.5
40 mph				
MY 97	64.2	54.8	44.5	51.5
MY 99	60.0	59.8	44.5	51.8
45 mph				
MY 97		61.8		55.8
MY 99		52.6		56.5

B. 30 Mph Unbelted Barrier Data: MY99 vs Pre-MY98 and MY98 vs pre-MY98 Comparisons

Table A-10a
MY1998 vs Pre-MY98
48 kmph (30 mph) Unbelted Barrier, 50th Percentile Male Dummy Responses*
DRIVER

Model Year	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)	Test Vehicle Sample (n)
Pre-1998	280	**	47.93	38.63	5-6
1998	205	0.300	47.34	39.96	9

* Average values shown.
** Pre-98 models did not use dummy neck instrumentation.
Make/models were matched.

Table A-10b
MY1999 vs Pre-MY98
48 kmph (30 mph) Unbelted Barrier, 50th Percentile Male Dummy Responses*
DRIVER

Model Year	HIC_{15}	Nij	Chest g's	Chest Deflection(mm)	Test Vehicle Sample (n)
Pre-1998	231	**	44.25	36.0	6
1999	188	0.291	48.44	39.5	6

* Average values shown.
** Pre-98 models did not use dummy neck instrumentation.
Make/models were matched.

Table A-10c
MY1998 vs Pre-MY98
48 kmph (30 mph) Unbelted Barrier, 50th Percentile Male Dummy Responses*
PASSENGER

Model Year	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)	Test Vehicle Sample (n)
Pre-1998	194	**	43.8	20.1	4-6
1998	187	0.322	50.32	15	9

* Average values shown.
** Pre-98 models did not use dummy neck instrumentation.
Makes/models were matched.

Table A-10d
MY1999 vs Pre-MY98
48 kmph (30 mph) Unbelted Barrier, 50th Percentile Male Dummy Responses*
PASSENGER

Model Year	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)	Sample (n)
Pre-1998	247	**	45.7	18.74	6
1999	230	0.360	46.1	16.2	6

* Average values shown.
** Pre-98 models did not use dummy neck instrumentation.
Makes/models were matched.

NOTE: There were 6 - MY99 make/models (VRTC), 7 - MY98 make/models (VRTC) and 2 Ford vehicles, one was a confidential MMY and the other was a 1998 Ford Escort (non-confidential) for a total of 9 MY98 vehicles]. The [confidential MMY], 48 kmph (30 mph) unbelted tests by VRTC and [ ] are not included in Tables IV-10a -10d.

C. 30 Mph Unbelted Barrier Comparison by Specific Make/Models (MY99 vs Pre-MY98 and MY98 vs Pre-MY)

Table A-11a
MY99 vs. Pre-MY98 Matched Make/Models
48 kmph (30 mph) Unbelted Barrier, 50th Percentile Male Dummy
DRIVER

Make Model Year	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)
Dodge Intrepid Pre-98 1999	 239 403	 ** 0.349	 40.6 54.4	 33.6 44.8
Saturn Pre-98 1999	 N.D. 128	 ** 0.330	 33.0 36.8	 41.3 46.8
Ford Econoline Pre-98 1999	 161.7 87	 ** 0.219	 47.3 52.1	 31.4 37.1
Acura 3.5RL Pre-98 1999***	 N.D. 154	 N.D. 0.241	 N.D. 56.9	 N.D. 31.8
Ford Expedition Pre-98 1999	 201 178	 ** 0.307	 42.2 46.73	 27.7 28.1
Toyota Tacoma Pre-98 1999	 321 176	 ** 0.253	 46.4 43.7	 46.0 48.4

----- Missing data. N.D.= No Data Available. ** Pre-98 neck loads not measured.
*** 1999 Acura 3.5RL femur axial load exceeded mandated ICPL with a value of 13,349N.

Table A-11b
MY99 vs. Pre-MY98 Matched Make/Models
48 kmph (30 mph), Unbelted Barrier, 50th Percentile Male Dummy
PASSENGER

Make Model Year	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)
Dodge Intrepid				
Pre-98	212	**	52.4	19.5
1999	223	0.348	54.1	25.7
Saturn				
Pre-98	139	**	41.6	12.8
1999	200	0.314	40.2	9.2
Ford Econoline				
Pre-98	120	**	44.6	13.5
1999	226	0.322	45.8	7.3
Acura 3.5RL				
Pre-98	N.D.	N.D.	N.D.	N.D.
1999	367	0.408	49.8	11.6
Ford Expedition				
Pre-98	516	**	43.7	12.1
1999	132	0.310	51.0	19.6
Toyota Tacoma				
Pre-98	N.D.	N.D.	N.D.	N.D.
1999	173	0.480	35.6	23.5

--- Missing data
N.D. = No Data available.
**Pre-98 neck values not measured.

Table A-11c
MY98 vs. Pre-MY98 Matched Make/Models
48 kmph (30 mph) Unbelted Barrier, 50th Percentile Male Dummy
DRIVER

Make Model Year	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)
Ford Taurus Pre-98 1998	 337 181	 ** 0.265	 50.4 47.2	 33.06 21.9
Dodge Neon Pre-98 1998	 170 166	 ** 0.373	 47.3 43.5	 30.37 24.9
Toyota Camry Pre-98 1998	 159 231	 ** 0.366	 49.0 51.8	 46.2 38.1
Honda Accord Pre-98 1998	 500 51	 ** 0.215	 40.2 36.7	 N.D. 45.8
Dodge Caravan Pre-98 1998	 294 350	 ** 0.316	 47.5 48.0	 44.6 54.7
Ford Explorer Pre-98 1998 (VRTC)	 218 272	 ** 0.214	 53.2 44.4	 38.1 32.3
Confidential MMY	[ ]	[ ]	[ ]	[ ]

** Nij neck loads not measured.
N.D. = No data available.

For the driver MY98 vs pre-98MY, for 4 out of 6 vehicles the chest g's decreased an average of -4.8 g's and for 2 out of 6 vehicles chest g's increased an average of +1.65 g's. This is the opposite of the driver for MY99 vs pre-MY98.

Table A-11d
MY98 vs. Pre-98 Matched Make/Models
48 kmph (30 mph) Unbelted Barrier, 50th Percentile Male Dummy
PASSENGER

Make Model Year	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)
Ford Taurus Pre-MY98 1998	 167 191	 ** 0.313	 45.6 48.5	 N.D. 8.8
Dodge Neon Pre-MY98 1998	 125 297	 ** 0.379	 46.1 **61.4**	 23.61 16.02
Toyota Camry Pre-MY98 1998	 401 236	 ** 0.201	 47.3 35.1	 16.93 16.7
Honda Accord Pre-MY98 1998	 273 160	 ** 0.359	 40.2 45.0	 N.D. 13.11
Dodge Caravan Pre-MY98 1998	 70 249	 ** 0.384	 39.0 53.4	 24.6 20.3
Ford Explorer Pre-MY98 MY98 (VRTC)	 131 186	 ** 0.254	 44.6 48.2	 17.0 10.3
Confidential MMY	[ ]	[ ]	[ ]	[ ]

** Nij neck loads not measured.
N.D. = No data available.
Bold Number indicate measured value exceeds mandated ICPL.

Pass Rates by Response Type: 30 Mph Unbelted Barrier Tests

Table A-12a
Pass Rate - MY98 vs Pre-MY98
48 kmph (30 mph) Unbelted Barrier, 50th Percentile Male Dummy
DRIVER

Model Year		n	HIC_{15}	Nij	Chest g's	Chest Deflection
Pre-1998	Pass Rate %	6	100	--*--	100	100
1998	Pass Rate %	9	100	100	100	100

* Nij data not collected by VRTC
Overall MY98 femur axial load Pass Rate was 100%.

Table A-12b
Pass Rate -MY99 vs Pre-MY98
48 kmph (30 mph), Unbelted Barrier, 50th Percentile Male Dummy
DRIVER

Model Year		n	HIC_{15}	Nij	Chest g's	Chest Deflection
Pre-1998	Pass Rate %	6	100	--*--	100	100
1999	Pass Rate %	7	100	100	100	100

* Nij data not collected by VRTC.
** 1999 Acura 3.5 RL left femur axial load of 13,349 N exceeded the ICPL of 10,000N.
Overall MY99 driver-side femur axial load Pass Rate was 83.3% (5/6).

Table A-12c
Pass Rate - MY98 vs Pre-MY98
48 kmph (30 mph), Unbelted Barrier, 50th Percentile Male Dummy
PASSENGER

Model Year		n	HIC_{15}	Nij	Chest g's	Chest Deflection
Pre-1998	Pass Rate %	6	100	--*---	100	100
1998	Pass Rate %	9	100	100	88.9 **	100

* Nij data not collected by VRTC.
** 1998 Dodge Neon passenger-side had a chest g's of 61.4 g's.
Overall MY98 passenger-side femur axial load Pass Rate was 100%.

Table A-12d
Pass Rate - MY99 vs Pre-MY98
48 kmph (30 mph), Unbelted Barrier, 50th Percentile Male Dummy
PASSENGER

Model Year		n	HIC_{15}	Nij	Chest g's	Chest Deflection
Pre-1998	Pass Rate %	6	100	-*---	100	100
1999	Pass Rate %	7	100	100	100	100

* (-----) missing Nij data needed from VRTC.
Overall MY99 passenger-side femur axial load Pass Rate was 100%.

D. Final Rule Full-Forward Seating Procedure vs. 3" Rearward, 5th Percentile Female Dummy.

The commenters requested that NHTSA consider a seating position more in line with the UMTRI study and consistent with how people actually adjusted their outboard seats fore/aft in the real-world. As shown in Tables A-13a and A-13b, the agency conducted two 48 kmph (30 mph) unbelted barrier tests with the 5th percentile female dummy using a modified seating procedure. Rather than having the driver and passenger seat full-forward as specified in the SNPRM (same as the final rule), the seats were adjusted rearward about 76 mm (3 inches) from full-forward. Moving the seat back 3" from full-forward matches the UMTRI procedure and provides approximately a 10" clearance between the 5th percentile female dummies chest and the steering wheel. The UMTRI procedure for the seat back angle was also employed in these two tests.[6]

[6] ATD Positioning based on Driver Posture and Position, Manary, M.A., Reed, M.P., Flannagan, C.A.C., and Schneider, L.W., University of Michigan Transportation Research Institute (UMTRI), 1998 SAE International Congress and Exposition, Society of Automotive Engineers, SAE #983163.

Table A-13a
48 kmph (30 mph), 0 Degrees, Unbelted Barrier, 5th Percentile Female Dummy
Responses of a Modified Seating Procedure (3" rearward from full-forward)
Compared to Full-Forward Seating Procedure
DRIVER

	HIC_{15}	**Nij***	**Chest g's**	**Chest (mm) Deflection**	**Max. Femur Loads (N)**	**Seating Procedure**
1999 Acura 3.5 RL ** (VRTC) Single Stage	149	1.294	47.4	41.0	3908	SNPRM full-forward (n=1)
1999 Acura 3.5 RL** (VRTC) Single Stage	68	0.735	48.44	38.9	5645	Modified 3" rearward (n=1)
4- Confidential MMY (Avg.)*** 3- Stage 1 1- Stage 1+2	[ ]	[ ]	[ ]	[ ]	[ ]	SNPRM full-forward (n=4)
2000 Ford Taurus**** (VRTC) Stage 1	158	0.426	54.44	49.5	6208	Modified 3" rearward (n=1)
5th ICPLs	700	1.0	60	52	6800	

* Neck compression and tension Peak Limits not exceeded for any of these tests.
Acura 3.5 RLs were tested post-SNPRM (n=1) and 12/13/99 (n=1).
** Single stage inflators for 1999 Acura 3.5 RLs.
*** [This information is confidential.]
**** Low Power Mode (Stage 1 + 100 ms gap + Stage 2). A production 2000 Ford Taurus purchased at a dealership. This data can been released.
- The agency is aware that within 100 mm (4") of the seat being full-forward, the [confidential MMY] fires only Stage 1 on the driver-side.
- Peak neck compression/tension limits not exceeded on any of these tests.
[ ] confidential data removed.

Table A-13b
48 kmph (30 mph), 0 Degrees, Unbelted Barrier, 5th Percentile Female Dummy
Responses of a Modified Seating Procedure (3" rearward from full-forward)
Compared to Full-Forward Seating Procedure
PASSENGER

	HIC_{15}	**Nij***	**Chest g's**	**Chest (mm) Deflection**	**Max. Femur Loads (N)**	**Seating Procedure**
1999 Acura 3.5 RL ** (VRTC) Stages 1+2	307	0.775	55.5	12.3	4631	SNPRM full-forward (n=1)
1999 Acura 3.5 RL*** (VRTC) Stages 1+2	517	0.822	48.7	10.5	6440	Modified 3" rearward (n=1)
Confidential MMY **** (avg.) Stages 1+2	[ ]	[ ]	[ ]	[ ]	[ ]	SNPRM full-forward (n=3)
2000 Ford Taurus***** (VRTC) Stage 1+2	198	0.360	**70.12**	19.4	**6850**	Modified 3" rearward (n=1)
5th ICPLs	700	1.0	60	52	6800	

* Neck compression and tension Peak Limits not exceeded for any of these tests.
** Inflator Stages 1 + 2 used.
*** High Power Mode (Stages 1 + 2 fired simultaneously)
**** [This information is confidential.]
***** n=1 2000 Ford Taurus (VRTC) High Power Mode (Stage 1 + 5ms gap + Stage 2). A production 2000 Ford Taurus purchased from a dealership.
- Peak limits on neck compression/tension not exceeded in any of these tests.
[ ] confidential data removed.

Compared to the full-forward test condition (same speed and MMY test vehicles), moving the dummy rearward by 3" should, at least theoretically, reduce overall test stringency. Being further away from the steering wheel or instrument panel reduces the punch-out and membrane interaction affects between the air bag/dummy, but the added 76 mm (3 inches) of space may have contributed to added dummy horizontal velocity. Comparing the same make/model/ years (1999 Aura 3.5RL and confidential MMY), with and without seating procedure changes, HIC_{15} results were mixed (50/50) with some increases, Nij and chest deflection decreased in 3 out of 4 test conditions (75%), chest g's increased in 3 out of 4 test conditions (75%) and femur loads increased in 4 out of 4 test conditions (100%).

For the 1999 Acura 3.5 RL driver-side Nij dropped from 1.294 to 0.735 with the modified seating procedure, whereas the passenger-side Nij slightly increased but still did not exceed the proposed ICPL value. From a compliance point of view, the 1999 Acura 3.5 RL went from failing to comply with the SNPRM seating procedure to passing with the modified procedure.

For the confidential MMY, on the driver-side, all 4 prior tests failed chest deflection with the SNPRM seating procedure but now passed with the modified seating procedure. On the passenger-side of the confidential MMY, two prior tests had failed chest g's, and in the case of the modified seating procedure, this was exacerbated (increased to 70.12 g's), increasing the likelihood of failing chest g's for this model. Overall, the confidential MMY continued to not pass the ICPL values with or without the modified seating procedure.

E. 44 kmph (27.5 mph), Unbelted, FRB vs 48 kmph (30 mph), Unbelted FRB, 5th Percentile Female Dummy

NHTSA examined an alternative unbelted FRB test speed between 40 kmph (25 mph) and 48 kmph (30 mph) using the 5th percentile female dummy, namely - 44 kmph (27.5 mph). As shown in Table A-14, NHTSA conducted two full-scale, unbelted fixed rigid barrier tests at 27.5 mph using the 5th percentile female dummy. The driver and passenger seats were positioned full-forward in accordance with the final rule. The 2000 Ford Taurus (production vehicle purchased from a dealer) driver and passenger dummy passed all required ICPL values. The 1999 Acura 3.5 RL passed all mandated ICPL values except the driver-side Nij.

Compared to prior 30 mph unbelted tests using the 5th percentile dummy for the 1999 Acura RL, the 2.5 mph reduction in speed resulted in an overall reduction in dummy responses for the Acura RL with the exception of chest deflection which increased by 7.4 mm (21% increase) for this one test. The 1999 Acura failed to comply at 30 mph but passed at 27.5 mph as driver Nij was reduced from 1.294 to 0.96, respectively. The 1999 Acura passenger-side passed at both test speeds.

Table A-14
44 kmph (27.5 mph) 0 degrees, Unbelted Barrier, 5th Percentile Female Dummy
(Seating Procedure - Seat Full-Forward)

MMY	**Dummy Type**	**HIC$_{15}$**	**Nij***	**Chest g's**	**Chest Deflection (mm)**	**Femur (N) (Max.)**
2000 Ford Taurus	**Driver** 5th ** Stage 1	101	0.819	51.77	44.95	5056R
2000 Ford Taurus	**Passenger** 5th *** Stages 1+2	126	0.391	47.8	10.21	5129R
1999 Acura 3.5 RL	**Driver** 5th Single Stage	122	0.96	38.24	42.9	4700R
1999 Acura 3.5 RL	Passenger 5th **** Stages 1+2	173	0.532	43.96	9.38	5129R
ICPLs	5th	700	1.0	60	52	6,800

Bold Numbers exceed mandated ICPL values.
* Neck compression and tension Peak Limits not exceeded for any of these tests.
** Low Power Mode (Stage 1 + 100 ms gap + Stage 2)
*** High Power Mode (Stage 1 + 5ms gap + Stage 2)
**** High Power Mode (Stage 1 and Stage 2 fired simultaneously).
- 2000 Ford Taurus test conducted by VRTC (V3225) 12/09/99 at 27.37 mph (actual). Production design purchased at a dealership.
- 1999 Acura 3.5 RL test conducted by VRTC 12/10/99 at 27.63 mph (actual).
- Peak limits for neck compression/tension not exceeded in any of these tests.

R = right femur load was the maximum.

F. Multi-Stage Inflators

A. Two Stage Inflators

The purpose of Table A-15 is to compare the magnitude of responses for Stage 1 vs Stages 1+2 for the same crash condition, or static OOP test condition, for several Hybrid III dummy sizes. This table contains several matched pair examples of Stage 1 vs Stage 1+2 inflation levels from which the difference in magnitude of the two inflation levels can be judged for a few specific make models. Stage 1 (only) improves Nij responses compared to Stage 1+2.

The Acura RL has a two stage inflator that can vary inflation force according to crash severity and Mercedes will also introduce two stage inflator technology. By the MY 2000, it is anticipated that BMW and Acura models will have dual threshold restraint systems (higher inflation threshold levels if the occupant is belted) with two stage inflator technology.[7] MY 2000 Ford Taurus will have a dual threshold restraint system with two stage inflator technology. MY 2000 Toyota models are expected to employ 2 stage inflators and GM as well as Chrysler are expected to employ 2 stage inflator technology in MY 2001.[8] TRW's Gen5E crash sensor contains dual-stage air bag inflator interfaces as well as crash-severity algorithm and buckle switch sensing to provide staged inflation capabilities.[9] Its firing squib configuration will allow for personalized deployment of all air bags and pre-tensioners.

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[7] The 2000 BMW 740 has dual stage inflators. The Washington Times, AutoWeek Section, page E12, January 14, 2000.

[8] Source: IIHS Status Report, Volume 34, No. 4, April 24, 1999.

[9] SAE's Automotive Engineering Magazine, November 1999, page 77.

Table A-15
Dual Stage Inflator Comparison Stage 1 vs Stage 1+2
30mph Unbelted Barrier Crash Tests and Static OOP Position Tests
Seating Procedure per Final Rule

MY	MM	Test Date	HIC_{15}	Nij	Chest g's	Chest Deflect (mm)	Left Femur (N)	Right Femur (N)
Driver 50%-ile								
Confid.	[ ]	6/28/99, VRTC Stage 1+2 *	[ ]	[ ]	[ ]	[ ]		[ ]
Driver 5th%F								
Confid.	[ ]	Stage 1	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Confid.	[ ]	Stage 1	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Confid.	[ ]	Stage 1+2	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Confid.	[ ]	11/16/99, VRTC Stage 1	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Pass 50th%M								
Confid.	[ ]	6/28/99, VRTC Stage 1+2	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Pass. 5th%F								
Confid.	[ ]	Stage 1+2	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Confid.	[ ]	Stage 1+2	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Confid.	[ ]	11/16/99, VRTC Stage 1+2	[ ]	[ ]	[ ]	[ ]		[ ]
6-Year- Old Position 1								
1999	Acura RL	3960014 Stage 1+2	191	**1.31**	19.5	10.7		
1999	Acura RL	3960015 Stage 1 (repeat)	88	0.94	19.4	8.2		
6-Year-Old Position 2								
1999	Acura RL	3960016 Stage 1+2	113	0.93	16	9.53		
1999	Acura RL	3960002 Stage 1	101	0.830	18	3.02		

Table A-15 Footnotes * VRTC Test #V3150 Stages 1+2 were deployed for both the driver and passenger. ** The confidential MMY tested by VRTC and [ ] were called pre-production prototypes. From a crash dynamics point of view, the [confidential MMY] and the [confidential MMY] are equivalent or identical test vehicles. For [ ], stages 1+2 are about equivalent to a current depowered single stage inflator. **Bold Numbers** indicate measured value exceeded ICPL. [ ] confidential data removed.

G. Test Procedure Repeatability/Reproducibility

In the NHTSA/Transport Canada cooperative research program two repeatability test series were conducted for the belted, in-position, 5th percentile female test dummy. For HIC_{15} and Nij, the 40 kmph (25 mph) ODB belted test had more variability than the 48 kmph (30 mph) full frontal barrier test. Table A-16 compares the variability of the ODB test to a 48 kmph (30 mph) full frontal barrier test. It is believed that the higher HIC_{15} and Nij variability in the ODB test is due to; (1) structural crush variability and (2) "fire time" variability. The 40 kmph (25 mph) ODB, 40% overlap, belted test procedure has been mandated specifically to help reduce "fire time" variability and enhance soft pulse crash sensing by leading to improved crash sensor and/or crash data processing algorithm design.

Table A-16
Test Procedure Repeatability
5th Percentile Female Dummy, Belted, 40 kmph (25 mph) ODB & 48 kmph (30 mph) FRB
(Transport Canada)

Test Speed	**Occupant Position**	**HIC_{15} %CV ***	**Nij %CV**	**Chest g's %CV**	**Chest Deflection %CV**	**Sample (n)**
25 Mph ODB (L)	Driver	+/-42.8%	+/-55.7%	+/-3.41%	+/-8.90%	3 - 1998 Cavalier
25 Mph ODB (L)	Pass.	+/-28.8%	+/-20.1%	+/-4.63%	+/-12.3%	3- 1998 Cavalier
30 Mph	Driver	+/-18.5%	+/-20 %	+/-7.19%	+/-3.50%	3 - 1999 Cavalier
30 Mph	Pass.	+/-4.19%	+/-10.5 %	+/-8.12%	+/-7.23%	3 -1999 Cavalier

* % CV = percent coefficient of variation = Standard Deviation (n-1) divided by the Mean X 100%. This is interpreted as +/- the value. ODB = 40% Offset Deformable Barrier Test, Left-side Impact.

The delay in inflator fire times due to the soft crash pulse is believed to cause out-of-position risk for occupants.

In prior agency analyses of test procedures (e.g., FMVSS 201, 214,), a %CV <= 5% is considered "excellent" and 5-10 % is considered "good" for repeatability and reproducibility tests. It is known from prior crash test experience to expect a high HIC variability (10-20%) based on Gauthier/Machey 1982 Chevy Citation NCAP repeatability test series.[10] The 40 kmph (25 mph) ODB test had a HIC_{15} variation range of about +/- 29 to +/- 43 percent and Nij variation range of +/-20 to +/- 56 percent. The full frontal test, although at a higher speed, had a lower HIC_{15} variability range of +/- 4 to +/-19 percent and an Nij variability range of +/-11 to +/- 20 percent. The range of %CV values for chest acceleration (4-8%) and chest deflection (3-12%) are reasonable for both of these test procedures. It is important for the manufacturers to understand the variability of the test procedures so they can set their design goals.

5th Percentile Female Dummy: Based on the subject belted ODB test data at 25 mph, HIC_{15} and Nij had a variation of +/- 43 percent and +/- 56 percent, respectively. Driver and passenger HIC_{15} may not be easily accommodated without some vehicle re-design effort, whereas Nij may be less of a problem for some make/models. Chest g's and chest deflection can be more easily accommodated with vehicles "as designed."

[10] Results, Analysis and Conclusions of NHTSA's 35 Mph Frontal Crash Test Repeatability Program, Machey, J.M. and Gauthier, C.L., Office of Market Incentives, Rulemaking, NHTSA/DOT, 1984 SAE International Congress and Exposition, Detroit, Michigan, SAE Paper No. 840201.

At 30 mph belted barrier, high Nij variability would be a "marginal" problem on the driver-side, but not on the passenger-side. Chest g's, fortunately had much lower variability (+/- 4-8%) as average chest g's, both belted and unbelted are in the mid to high 40's. Chest deflections are sufficiently low in both belted and unbelted cases that variability is not an issue.

50th Percentile Male Dummy: Assuming the 40 kmph (25 mph) ODB variability is the worse case scenario, it appears that the full-scale unbelted barrier data for MY 1998 and 1999 compliance margins would be sufficient to accommodate a 43 percent and 56 percent variability for HIC_{15} and Nij, respectively.

Test Procedure Reproducibility

The reproducibility of the confidential MMY data at 48 kmph (30 mph) based on the unbelted 5th percentile dummy was examined. This accounts for crash test response variations due to: (1) vehicle systems, (2) test dummies, (3) test equipment, and (4) test procedures. NHTSA has studied the FMVSS No. 214 dynamic side impact test procedure and found about a +/-10 to +/-20 percent range in reproducibility across TTI(d) and pelvic g's considering both the front driver and rear passenger.[11] The data in Table A-17 was not from a specifically designed repeatability/ reproducibility test series and involved two different test facilities (VRTC and [ ]) and probably 4 - different 5th percentile female crash test dummies. The unbelted driver-side was much more reproducible than the unbelted passenger-side.

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[11] Final Regulatory Impact Analysis, New Requirements for Passenger Cars to Meet a Dynamic Side Impact Test FMVSS 214, August 1990, Office of Regulatory Analysis, (NPP-20), NHTSA/DOT, Publication No. DOT HS 807 641.

As shown in Table A-17, the +/-11.4% for the driver-side chest deflection is critical for the confidential MMY as zero out of 4 tests passed chest deflection. The +/- 45.8% for the passenger-side Nij is critical, as the confidential MMY tested by [ ] recorded an Nij of [confidential data removed]. The +/-14.7% for the passenger-side chest g's is also critical as two out of three tests had chest g's greater than 60 g's [confidential data removed]. However, the +/- 43.5% for passenger-side chest deflection is not critical as responses were significantly below the required ICPL values. The unbelted confidential MMY reproducibility test results are consistent with, and within the range of, the belted Transport Canada repeatability results in Table A-16 above.

Table A-17
Test Procedure Reproducibility
5th Percentile Female Dummy, Unbelted, 48 kmph (30 mph), FRB
Confidential MMY

Test Speed	Occupant Position	HIC_{15} %CV *	Nij %CV	Chest g's %CV	Chest Deflection %CV **	Sample (n)
48 kmph (30 Mph)	Driver	+/-20.3%	+/-10.6%	+/-6.23%	+/-11.4%	n=4 confid. MMYs
48 kmph (30 Mph)	Passenger	+/-28.2%	+/-45.8%	+/-14.7%	+/-43.5%	n=3 confid. MMYs

* The driver-side had n=3 Stage 1 deployments and n=1 Stage 1+2 deployment. The passenger-side had n=3 Stage 1+2 deployments. All vehicles were pre-production prototypes.
** %CV = percent coefficient of variation = Standard Deviation (n-1) divided by the Mean X 100%. This is interpreted as +/- the value.

Influence on Other 48 kmph (30 mph) Unbelted Tests (neglecting the confidential MMY Tests)

There were 12 test vehicles at 48 kmph (30 mph), FRB, unbelted 5th percentile female dummy, 4 of which were confidential MMY. For the driver-side unbelted at 48 kmph (30 mph) FRB, the other 8 vehicles can easily accommodate +/- 20% HIC_{15} variability, whereas +/-10.5% for Nij can only be accommodated by 4 out of 8 (50%) of the other vehicles tested. Chest g's and chest deflection variation of +/- 6.23% and +/-11.4%, respectively, would not appear to pose a need for vehicle re-design.

For the passenger-side, unbelted at 48 kmph (30 mph) FRB, the 8 remaining vehicles can easily accommodate a +/- 28% variation in HIC_{15}, whereas only 1 out of 8 can accommodate a +/- 45.8% variation in Nij. A passenger-side chest g's variation of +/- 14.7% will not create re-design issues for 6 out of 8 of the remaining test vehicles and a chest deflection variability of +/- 43.5% can easily be accommodated as deflection values are significantly below the mandated ICPL values.

H. Margins of Compliance

Toyota Comments (Docket No. 99-6407-47)

Toyota submitted confidential unbelted, 48 kmph (30 mph) FRB, 50th percentile male dummy, test data for Model "X" SUV which has been certified to the current FMVSS No. 208 sled test. This data is shown in Tables A-18 (Driver) and A-19 (Passenger). Toyota stated in their comments;

"...the driver-side exceeds the IARVs for both chest g's and chest deflection and exceeds the compliance margins" and "...for the passenger side, chest g's and femur loads do not meet the criteria."[12] Toyota concludes "...for the same vehicle subjected to a 40 kmph (25 mph) FRB test for both the driver and passenger side, test results indicate that Model "X" SUV could be certified to meet the requirements."

Table A-18
Model "X" SUV, Unbelted, FRB, 50th Percentile Male Dummy
Confidential
DRIVER

	48 kmph (30 mph) FRB	**40 kmph (25 mph) FRB**	**Reduction in Response due to 25 mph Test Speed**
	Percent of IARV	Percent of IARV	Difference in Percentage
HIC_{15ms}	[ ]	[ ]	[ ]
Neck Tension	[ ]	[ ]	[ ]
Neck Compression	[ ]	[ ]	[ ]
Neck Flexion Moment	[ ]	[ ]	[ ]
Neck Extension Moment	[ ]	[ ]	[ ]
Chest g's	[ ]	[ ]	[ ]
Chest Deflection	[ ]	[ ]	[ ]
Sternal Deflection Rate (SDR)	[ ]	[ ]	[ ]
Femur Load (R)	[ ]	[ ]	[ ]
Femur Load (L)	[ ]	[ ]	[ ]

- Model "X" SUV is certified to current 208 sled test [ ] confidential data removed.
- Percentages are approximate from submitted bar-charts.
- Assumes the IARVs referred to by Toyota are the same as SNPRM Injury Criteria.
- **Bold Number** indicates a Compliance Margin (CM) less than the 20 percent suggested by the manufacturers, where Compliance Margin (%) i = [1 - R i /ICPL i] $_{DUMMY\,i}$ X 100% and Ri = dummy response value in a particular high speed or static test.

[12] For a 60 g's chest acceleration requirement, a design goal of 48 g's or 20 percent lower than the standard allows has often been cited by the manufacturers.

Table A-19
Model "X" SUV, Unbelted, FRB, 50th Percentile Male Dummy

Confidential **PASSENGER**

	48 kmph (30 mph) FRB	**40 kmph (25 mph) FRB**	**Reduction in Response due to 25 mph Test Speed**
	Percent of IARV	Percent of IARV	Difference in Percentage
HIC_{15ms}	[ ]	[ ]	[ ]
Neck Tension	[ ]	[ ]	[ ]
Neck Compression	[ ]	[ ]	[ ]
Neck Flexion Moment	[ ]	[ ]	[ ]
Neck Extension Moment	[ ]	[ ]	[ ]
Chest g's	[ ]	[ ]	[ ]
Chest Deflection	[ ]	[ ]	[ ]
Sternal Deflection Rate (SDR)	[ ]	[ ]	[ ]
Femur Load (R)	[ ]	[ ]	[ ]
Femur Load (L)	[ ]	[ ]	[ ]

- Model "X" SUV is certified to current 208 sled test.
- Percentages are approximate from submitted bar-charts.
- Assumes the IARVs referred to by Toyota are the same as SNPRM Injury Criteria.
- **Bold Number** indicates a compliance margin less than the 20 percent suggested by the manufacturers, where Compliance Margin (%) i = [1 - R i /ICPL i] $_{DUMMY\,i}$ X 100% and Ri = dummy response value in a particular high speed or static test.

[ ] confidential data removed.

As shown in Tables A-20 and A-21, Toyota also submitted 48 kmph (30 mph) FRB, unbelted, 50th percentile male dummy, crash test data for several test vehicles equipped with depowered air bags. Toyota stated in their comments,

"...vehicles X, Y and Z exceed acceptable compliance margins for several IARVs, and in some instances, actually exceed allowable limits. [vehicle X is the same as Model "X" described above.]

Toyota concluded in their comments

"...they can not comply with the 48 kmph (30 mph) unbelted rigid barrier test unless the air bag inflator is **re-powered** to higher levels, therefore, increasing the potential injury risk for "at risk" groups."

Table A-20
48 kmph (30 mph) FRB, Unbelted, 50th Percentile Male Dummy
Percent of SNPRM Injury Criteria
DRIVER

	Model "X"	Model "Y"	Model "Z"	Model "A"
HIC_{15ms}	[ ]	[ ]	[ ]	[ ]
Nij	[ ]	[ ]	N.D.	N.D.
Chest g's	[ ]	[ ]	[ ]	[ ]
Chest Deflection	[ ]	[ ]	[ ]	[ ]
Femur Load (R)	[ ]	[ ]	[ ]	[ ]
Femur Load (L)	[ ]	[ ]	[ ]	[ ]

-Models X, Y, Z & A are Toyota models currently in production with current generation of depowered air bags.
- Percentages are approximated from submitted bar-chart information.
- **Bold Number** indicates a compliance margin less than the 20 percent suggested by the manufacturers.
[ ] confidential data removed.

Table A-21
48 kmph (30 mph) FRB, Unbelted, 50th Percentile Male Dummy
Percent of SNPRM Injury Criteria
PASSENGER

	Model "X"	Model "Y"	Model "Z"	Model "A"
HIC_{15ms}	[ ]	[ ]	[ ]	[ ]
Nij	[ ]	[ ]	N.D.	N.D.
Chest g's	[ ]	[ ]	[ ]	[ ]
Chest Deflection	[ ]	[ ]	[ ]	[ ]
Femur Load (R)	[ ]	[ ]	[ ]	[ ]
Femur Load (L)	[ ]	[ ]	[ ]	[ ]

- **Bold Number** indicates a compliance margin less than the 20 percent suggested by the manufacturers.
-Models X, Y, Z & A are Toyota models currently in production with current generation of depowered air bags.
- Percentages are approximated from submitted bar-chart information.
[ ] confidential data removed.

Toyota on Compliance Margins and Reproducibility (Non-confidential)

Toyota stated in their comments,

> "... NHTSA asserted in its preamble that adequate compliance margins can be maintained at less than the roughly 20 percent manufacturers suggested [value] w[h]ere required. Toyota believes that NHTSA's assumptions do not account for the practical issues of wide variations in test results, not only vehicle-to-vehicle, but also test lab-to-test lab. Unfortunately, these variations are a real world consequence of vehicle development and compliance testing, and therefore they too must be considered by the manufacturer when certifying compliance."

Toyota submitted (non-confidential) driver-side 30 mph FRB, unbelted, 50th percentile male dummy, margin of compliance data for 5 **pre-depowered** test vehicles (1992 Camry, 1995 Tercel, 1996 RAV4, 1996 4Runner, and 1994 Celica.) generated by Toyota (#1, #2 & #3), compliance contractor (#1 & #2) and what Toyota calls a "Laboratory." These data are presented in Tables A-22 through A-26.

Table A-22
48 kmph (30 mph FRB), Unbelted, 50th Percentile Male Dummy
Percent of FMVSS 208 Injury criteria
1992 Toyota Camry, Driver

	Compliance Contractor #1	Compliance Contractor #2	Toyota	Max. Diff. Contractor. vs Toyota
HIC $_{15ms}$	42	34	15	+27
Chest g's	**112**	**90**	**95**	+22
Chest Deflection	58	70	42	+28

Bold Numbers indicate compliance margin is less than the 20 percent suggested by the manufacturers.

Table A-23
48 kmph (30 mph) FRB, Unbelted, 50th Percentile Male Dummy
Percent of FMVSS 208 Injury criteria
1995 Toyota Tercel, Driver

	Compliance Contractor	Toyota #1	Toyota #2	Laboratory	Max. Diff. Contract. vs Toyota	Max. Diff. Lab vs Toyota
HIC $_{15ms}$	45	41	25	40	+20	+15
Chest g's	**93**	71	**95**	**92**	+22	+21
Chest Deflection	25	30	N.D.	N.D.	-5	

Bold Numbers indicate the compliance margins are less than 20 percent suggested by the manufacturers.

Table A-24
48 kmph (30 mph) FRB, Unbelted, 50th Percentile Male Dummy
Percent of FMVSS 208 Injury criteria
1996 Toyota RAV4, Driver

	Toyota #1	Toyota #2	Toyota #3	Max. In-house Variance (%)
HIC $_{15ms}$	30	40	35	10
Chest g's	75	**88**	**90**	15
Chest Deflection	50	52	48	4

Bold Numbers indicate that the compliance margin is less than 20 percent suggested by the manufacturers.

Table A-25
48 kmph (30 mph) FRB, Unbelted, 50th Percentile Male Dummy
Percent of FMVSS 208 Injury Criteria
1996 4Runner, Driver

	Compliance Contractor	Toyota #1	Toyota #2	Max. Diff. Contractor vs Toyota
HIC_{15ms}	80	43	15	+65
Chest g's	**98**	**85**	**82**	+16
Chest Deflection	34	60	27	-26

Bold Numbers indicate that the compliance margin is less than 20 percent suggested by the manufacturers.

Table A-26
48 kmph (30 mph) FRB, Unbelted, 50th Percentile Male Dummy
Percent of FMVSS 208 Injury criteria
1994 Toyota Celica, Driver

	Laboratory	Toyota	Max. Diff. Lab vs Toyota
HIC $_{15ms}$	35	30	+5
Chest g's	**88**	65	+23
Chest Deflection	58	55	+3

Bold Numbers indicate that the compliance margin is less than 20 percent suggested by the manufacturers.

NHTSA agrees with Toyota that there are full-scale crash test reproducibility concerns and that results may vary considerably based on the driver-side for the 5 Toyota pre-depowered air bag designs. The data presented by Toyota clearly shows compliance margins of less than the manufacturer suggested 20 percent, particularly for chest g's. Toyota's Model "X" results shown earlier suggest these smaller or reduced compliance margins for chest g's at 30 mph FRB, unbelted dummy, are not in the certifiable range (based on the industry's definition). In addition, the data clearly shows that compared to Toyota's in-house tests, outside testing sources easily produce results that are almost consistently 20-25 percent higher (up to 65 percent in one case). The data presented by Toyota effectively illustrates the wide variation in crash test results that must be taken into account by automobile designers.

Toyota does not agree with NHTSA that the Toyota Tacoma can easily pass all the pertinent injury criteria for the 30 mph unbelted test condition with large margins. As shown in Table A-27a and Table A-27b, Toyota submitted confidential test data; (1) to show that when NHTSA tested the 2WD 1999 Toyota Tacoma pickup truck it "passed," whereas when Toyota tested the 4WD version of the same MMY, it "failed" and (2) to support their position that there are inadequate margins of compliance and, therefore, the vehicle is not certifiable.

Table A-27a
48 kmph (30 mph) FRB, Unbelted Test Condition
Percent of SNPRM Injury Criteria
1999 Toyota Tacoma Xtracab, 50th Percentile Male & 5th Percentile Female Dummies

Toyota Data Confidential **DRIVER**

	NHTSA 2WD Response	NHTSA 2WD Percent	NHTSA 2WD Response	NHTSA 2WD Percent	Toyota 4WD Response	Toyota 4WD Percent
ATD Type	50th	50th	5th	5th	50th	50th
HIC $_{15ms}$	176	25%	199	28%	[ ]	[ ]
Nij $_{(SNPRM)}$	0.33	33%	0.48	48%	[ ]	[ ]
Chest g's	43.7	73%	52.3	**87%**	[ ]	[ ]
Chest Deflection	48.4	77%	51.4	**99%**	[ ]	[ ]
CTI $_{(NPRM\ only)}$	---	---	---	---	[ ]	[ ]

Bold Numbers indicate a margin of compliance less than the 20 percent suggested by the manufacturers.
[ ] confidential data removed.

Table A-27b
48 kmph (30 mph) FRB, Unbelted Test Condition
Percent of SNPRM Injury Criteria
1999 Toyota Tacoma Xtracab, 50th Percentile Male & 5th Percentile Female Dummies

Toyota Data Confidential **PASSENGER**

	NHTSA 2WD Response	NHTSA 2WD Percent	NHTSA 2WD Response	NHTSA 2WD Percent	Toyota 4WD Response	Toyota 4WD Percent
ATD Type	50th	50th	5th	5th	50th	50th
HIC $_{15ms}$	173	25%	380	54%	[ ]	[ ]
Nij $_{(SNPRM)}$	0.69	69%	2.65	**265%**	[ ]	[ ]
Chest g's	35.6	59%	42.2	70%	[ ]	[ ]
Chest Deflection	23.5	37%	4.2	7%	[ ]	[ ]
CTI $_{(NPRM\ only)}$	---	---	---	---	[ ]	[ ]

Bold Numbers indicate a margin of compliance less than the 20 percent suggested by the manufacturers.
[ ] confidential data removed.

Tables A-27a and 27b show the following:

1. Using the 50th percentile male dummy in the NHTSA (2WD) 1999 Toyota Tacoma test, the vehicle passed on both the driver-side and the passenger-side with margins of compliance greater than 20 percent. Overall, the vehicle passed the proposed SNPRM requirements as stated in the preamble.

2. Using the 5th percentile female dummy in the NHTSA (2WD) 1999 Toyota Tacoma test, the driver-side passed without adequate margins of compliance (less than 20%), and failed on the passenger-side. Overall, the 1999 Toyota Tacoma failed to meet the proposed SNPRM requirements using the 5th percentile female dummy. In the SNPRM, under Alternative 1 of the High Speed Test Requirements, the vehicle would have to pass using both the 50th and 5th percentile male and female dummies unbelted at 30 mph.

3. After analyzing the discrete response data obtained [confidentially] from Toyota for the 4WD version of the 1999 Toyota Tacoma test (50th percentile male dummy), the driver-side passed with adequate margins of compliance, but the passenger-side failed to comply. Overall, the 4WD version of the same make/model /year tested by NHTSA (and passed with adequate margins of compliance), failed to meet the SNPRM requirements using the 50th percentile male dummy.

4. The agency believes that the 2WD and 4WD Toyota Tacoma crash responses using the 50th percentile male dummy should not be compared to assess repeatability/reproducibility because of

potential crash pulse differences.[13] However, the independently derived margins of compliance should be assessed separately. The average GVWR of these two test vehicles may have varied by 500 lbs. due to the 2WD vs 4WD option alone. In addition, the 4WD option could affect front-end structure. For example, the 1999 Toyota Tacoma Xtracab, with 2WD option, the GVWR range is 2,910 - 4,498 lbs. and, for the 4WD option, the GVWR range is 3,245-5,104 lbs. or an average difference of 471 pounds (4,175 minus 3,704 lbs.).[14] Toyota's submission makes the point that even though the 2WD 1999 Toyota Tacoma might be certifiable at 30 mph using an unbelted 50th percentile dummy, the 4WD version would not be certifiable. Toyota's overriding concern is that if NHTSA returns to 30 mph unbelted barrier test, the manufacturers will be forced to increase inflator pressures beyond current levels and that this will increase risk to all occupants in the real-world crashes, especially OOP children and small adults.

In reviewing its films of the Tacoma tests, with the 5th percentile female sitting forward, the agency noticed that the air bag comes out high and catches the head area while the unbelted torso and lower body keep moving forward. This results in high neck loads. The agency believes changes in the way the air bag unfolds and other advanced air bag improvements could be tried to reduce these high neck loads.

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[13] The measured variation (%) between the 2WD and 4WD (NHTSA vs Toyota) 1999 Toyota Tacoma tests results were as follows: the driver-side showed [%],[%], [%] and [%] variation for HIC_{15}, Nij, chest g's and chest deflection, respectively. The passenger-side showed [%], [%], [%] and [%] variation for HIC_{15}, Nij, chest g's and chest deflection, respectively. In addition to vehicle differences, this reflects two facilities and 4 - 50th percentile test dummies. Percent Variation = [1/2 (X2 - X1) / ½ (X2 + X1)] X 100%

[14] 1999 Market Data Book, May 1999, Automotive News, Crain Communications, Inc. Detroit, Michigan

Ford on Compliance Margins (Confidential) 99-6407-38

Ford stated in their comments,

[" "]

I. Supplemental Full-Scale Crash Data

95th Percentile Male Dummy, Unbelted Full-Scale Crash Data

Table A-28
Confidential MMY (n=1)
48 kmph (30 mph) Unbelted Barrier, 95th Percentile Male Dummy Responses
Driver and Passenger

	HIC_{15}	Nij	Chest g's	Chest Deflection	Max. Femur Load (N)
Driver	[ ]	[ ]	[ ]	[ ]	[ ]
Passenger	[ ]	[ ]	[ ]	[ ]	[ ]
95th IARVs	700	1.0	55	70	10,000

Bold Numbers indicate applicable IARV is exceeded. Maximum allowable chest deflection, from a mechanical point of view, is approximately 114.3 mm for the 95th percentile male dummy.
[ ] confidential data removed.

Table A-29
Unbelted vs Belted
48 kmph (30 mph), 0 Degree Rigid Barrier, 50th Percentile Male Dummy
Average Responses (n=3) Pre-MY98 Make/Models
GM 208 Compliance Data

	Driver HIC_{36}	Driver Chest g's	Passenger HIC_{36}	Passenger Chest g's	n
Unbelted	316.7	46	376.7	46.7	3
Belted	360	44	400	44.3	3

* The sample (n=3) consisted of a 1997 Eldorado/Seville, a 1995-97 Buick Riviera, and a 1995-97 Oldsmobile Aurora.

Table A-30
Unbelted vs Belted
48 kmph (30 mph), 0 Degree Rigid Barrier, 50th Percentile Male Dummy
Average Responses - All GM Make/Models, MY1990-98
GM 208 Compliance Data

	Driver HIC_{36}	Driver Chest g's	Passenger HIC_{36}	Passenger Chest g's	n
Unbelted	325.4	45.23	289.8	42.87	62-115
Belted	410.9	45.9	396.4	44.1	14-31

* Different make/model/year GM test vehicles made up the 0 degree fixed rigid barrier data sets although there was some overlap in a few cases.

Table A-31
40 kmph (25 mph), 30 Degree Oblique, Left Impact
Unbelted, 50th Percentile Male & 5th Percentile Female Dummies
Confidential MMY

MY	MM	ATD Size	HIC_{15}	Nij	Chest g's	Chest Deflection (mm)	Max. Femur (N)
Driver							
Confidential MMY		5th *	[ ]	[ ]	[ ]	[ ]	[ ]
		50th *	[ ]	[ ]	[ ]	[ ]	[ ]
Passenger							
Confidential MMY		5th *	[ ]	[ ]	[ ]	[ ]	[ ]
		50th *	[ ]	[ ]	[ ]	[ ]	[ ]
5th ICPLs			700	1.0	60	52	6,800
50th ICPLs			700	1.0	60	63	10,000

* Stage 1 only required for these tests.
[ ] confidential data removed.

Tables A-32 shows 30 mph unbelted barrier test data for the confidential MMY using the 5th percentile female dummy, while Table A-33 shows 30 mph, 30 degree oblique unbelted test data for the confidential MMY using the 5th percentile female dummy. Table A-34 shows 25 mph unbelted barrier test data for the confidential MMY and confidential MMY using the 5th percentile female dummy.

Table A-32
48 kmph (30 mph), Fixed Rigid Barrier, Unbelted, 5th Percentile Female Dummy
CONFIDENTIAL MMYs

Occupant/Test Vehicle	HIC_{15}	Chest g's	Chest Deflection (mm)	Nij
Driver Test 1 Test 2 Test 3	[ ]* [ ]** [ ]*	[ ] [ ] [ ]	[ ] [ ] [ ]	[ ] [ ] [ ]
Passenger Test 2 Test 3	 [ ]** [ ]**	 [ ] [ ]	 [ ] [ ]	 [ ] [ ]
5th Percentile Female ICPL	700	60	52	1.0

Bold Numbers indicate measured values exceeded mandated ICPL.
* Stage 1 only fired. ** Stages 1+2 fired.
[ ] confidential data removed.

Table A-33
48 kmph (30 mph), 30 Degree Oblique, Right Impact, Rigid Barrier
Unbelted, 5th Percentile Female Dummy
CONFIDENTIAL MMY

Occupant/Test Vehicle	HIC$_{15}$	Chest g's	Chest Deflection (mm)	Nij
Driver*	[ ]	[ ]	[ ]	[ ]
Passenger*	[ ]	[ ]	[ ]	[ ]
5th Percentile Female ICPL	700	60	52	1.0

Bold Numbers indicate measured values exceeded mandated ICPL.
* Stage 1 only fired.
[ ] confidential data removed.

Table A-34
40 kmph (25 mph) Unbelted Rigid Barrier, 5th Percentile Female Dummy
CONFIDENTIAL MMY

Occupant/Test Vehicle	HIC$_{15}$	Chest g's	Chest Deflection (mm)	Nij
Driver				
Confidential MMY*	[ ]	[ ]	[ ]	[ ]
Confidential MMY**	[ ]	[ ]	[ ]	[ ]
Passenger				
Confidential MMY*	[ ]	[ ]	[ ]	[ ]
Confidential MMY**	[ ]	[ ]	[ ]	[ ]
5th Percentile Female ICPL	700	60	52	1.0

Bold Numbers indicate measured values exceeded mandated ICPL.
* Single stage inflator. ** Stage 1 fired.
[ ] confidential data removed.

APPENDIX B

This appendix responds to specific comments provided in response to the "Preliminary Economic Assessment, SNPRM, FMVSS 208, Advanced Air Bags", October 1999.

A. Response to Alliance (Docket 6407-#40) Critique of PEA:

Issue 1: The Alliance argues that analytical limitations are evident in NHTSA's analysis because the previous analysis where NHTSA predicted negative impacts for the sled test has been proven wrong by real world crash data. The Alliance then states that NHTSA's analysis of the 25 mph requirement will similarly be overestimated.

NHTSA agrees that the projected dis-benefits predicted in its analysis of depowering have not occurred. However, these estimates were a function of NHTSA's assumption that air bags would be depowered by 20-35 percent[1]. AAMA had commented that the average level of depowering would be 20 to 35 percent. This range was also seen in the prototype air bags supplied by the industry for NHTSA testing. In reality, these levels never materialized. Changes made by

[1] We characterized the 20-35 percent based on measurable parameters of the air bag, mainly peak pressure, but the change in rise rate percentages were comparable.

manufacturers were much more conservative.[2] The current analysis measures impacts for different design changes and is based on a much larger body of data. Therefore, it is not valid to use the results of the sled test analysis to predict the accuracy of the advanced air bag analyses.

The agency examined the average change in power between MY 1997 and MY 1998 (depowered) air bags based on data submitted to the agency from an Information Request sent to nine automobile manufacturers (for further information see "Air Bag Technology In Light Passenger Vehicles"). The agency believes the most important parameter for out-of-position testing is the rise rate (how fast the gas comes out of the module and fills the air bag). For driver air bags the rise rate was reduced an average of 22 percent between MY 1997 and MY 1998, and for passenger air bags the rise rate was reduced an average of 14 percent.

The agency believes a key parameter for in-position testing (e.g., in 30 mph testing) and for protection is the peak pressure of the air bag. The peak pressure is more important than the rise rate for the in-position testing, since the air bag is already filled or almost filled before the occupant engages the air bag. For driver air bags the peak pressure was reduced an average of 11 percent between MY 1997 and MY 1998, and for passenger air bags the peak pressure was reduced an average of 10 percent.

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[2] Further, extensive testing by NHTSA indicate that redesigned air bags meet the unbelted 30 mph test with the 50th percentile male dummy with, generally, a large compliance margin. This testing contradicts the claims that the 30 mph unbelted test led to the need for high-powered air bags.

The agency believes these differences in measured parameters help to explain why the real world crash data show a large reduction in the low speed out-of-position fatalities between MY 1997 and MY 1998 air bags, while at the same time there was no statistical difference in the protection of air bags provided in the real world data at high speeds. We note that there were many other changes made during this time period, including recessing the driver air bag, changes in vent size, fabric porosity, etc, that also probably contributed to improvements in safety.

Thus, it appears that the manufacturers found a way to reduce the rise rate, the factor most related to out-of-position aggressivity, more than the peak pressure, the factor more related to in-position protection. Peak pressure dropped about 10 percent, not the 20-35 percent predicted in the "Depowering" rule. Based on the data available to date, this appears to have reduced the out-of-position problem, while not having a negative impact on the in-position high speed cases.

Issue 2: The Alliance asserts that the agency bases its results on a single dummy in a single crash test in a single direction at a single speed to predict the benefits of advanced air bags in the variety of crash circumstances that occur in the real world. The Alliance cited a Harvard study of air bag effectiveness that criticized past NHTSA analyses as not adequately addressing the diversity in the vehicle fleet and driving public.

The Alliance misunderstood the agency's benefit estimate process. The agency has linked the laboratory dummy readings to real-world crash data and used the relationship to predict the life-saving potential of air bags. For example, through vigorous statistical analysis (Kahane), the agency found pre-MY 1998 air bags have an 11 percent effectiveness against fatalities[3]. This implies that the air bags passing 30 mph RFB unbelted 50th percentile male tests provided a weighted effectiveness of 11 percent across a whole range of impact speeds and diversity of vehicle occupants. The process reflects real world experience. The agency disagrees with the implication in the recent Harvard review. However, the agency acknowledges that to improve air bag system protection for different sizes of occupants, the agency needs to test dummies representing different sizes of occupants. Thus, the advanced air bags final rule has tests on a family of dummies to address the broader protection issue.

Issue 3: The Alliance states that NHTSA does not take into account compliance margins and other real world constraints such as NCAP and alternative crash configurations that manufacturers must address to develop acceptable safety systems.

NHTSA examined the results of a large number of tests of existing air bag systems in MY 1998/99 vehicles with air bags that were redesigned, which only had to meet the sled test. These vehicles were tested under the proposed 30 mph barrier test. In Chapter IV, the agency analyzed the pass/fail test results. We have also analyzed the compliance margins. For the 50th male dummy, 18 vehicles were tested for 5 parameters (Chest Gs, Chest Deflection, HIC, Nij, Femur load) and 2 frontal seating positions (driver and passenger), a total of 180 separate testing cells. In 148 of these, or 82%, the MY 1998/99 vehicles passed the 30mph rigid barrier test with

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[3] "Fatality Reduction by Air Bags, Analyses of Accident Data through Early 1996", NHTSA, August 1996, DOT HS 808-470. Overall (all crash modes) air bag fatality effectiveness is estimated to be11 percent, while air bag effectiveness in direct frontal impacts (12 o'clock impacts) is estimated to be 30 percent.

a compliance margin of over 20%. In 26 cases (15%) they passed, but with compliance margins of 20% or less. In 6 cases (3%), there were outright failures. For the 5th female, a total of 12 vehicles were tested for a total of 115 test cells. In the 5th female dummy tests, 94 (82%) of these passed with at least a 20% compliance margin, 7 (6%) passed with a low compliance margin, and 14 (12%) failed. The Alliance views the test failures and passes with less than a 20% margin as an indication of the technical difficulties that would occur under the higher (30mph) standard. NHTSA acknowledges that there will be design challenges for the industry. It is important to remember that none of these air bags systems were designed to pass a compliance test with a 5th percentile female dummy or an Nij criteria. However, the data clearly show that these challenges can be, and in most cases, already have been met in existing vehicle designs. NHTSA acknowledges that there will be costs associated with these design changes, but that is expected and is no basis in itself for rejecting a particular test requirement. NHTSA has clearly not ignored compliance issues, but rather has analyzed them and presented its best estimate of their impacts.

In response to the Alliance argument that other test requirements, such as the 30 mph belted test or NCAP (35 mph belted test), may limit the amount of depowering a manufacturer could do in a "25 mph unbelted test" world, the agency examined NCAP data. NCAP testing has shown that it is harder for light trucks to get better scores than it is for passenger cars, so the agency examined the last two years (1992 and 1993) in which there were a large number of light trucks tested with seat belts alone and no air bags. In 1992 and 1993 there were a total of 22 light trucks tested in NCAP with only seat belts. Eleven of those light trucks passed all of the 208 criteria and eleven did not. Of the eleven that did not pass, all eleven had HIC above 1,000 (36 millisecond) (8 of the

11 were between 1,000 and 1,225 HIC) and 4 vehicles had chest g's above 60 g's (3 of the 4 were at 61 or 62 g's). It is the agency's contention that the safety belt provides most of the benefit in meeting the belted test and that the dummy readings in belted tests would not be affected much by whether the air bag is designed to an unbelted 30 mph test or an unbelted 25 mph test. As shown in Tables IV-9a through IV-9e, the recent average NCAP test results with air bags are well within the FMVSS 208 injury criteria and there was essentially no clear trend in NCAP test scores, except that Nij had decreased some, comparing redesigned air bags with pre-MY 1998 air bags.

Issue 4: The Alliance states that NHTSA "assumes" that there will be significant effectiveness at 20 and 25 mph below and 15 mph above the design checkpoint. The Alliance then contrasts this with their own estimates, noting a different distribution of effectiveness rates for different speed ranges.

NHTSA's estimates of effectiveness by delta-V were based on real world data. NHTSA examined the impact of pre-1998 air bags on crashes stratified by delta-V to determine the relationship between design points and effectiveness. NHTSA then applied this same relationship to target populations grouped in 5 mph increments less than the pre-MY 1998 vehicles to estimate the impact on vehicles designed to a 25 mph (rather than a 30 mph) standard. This approach assumes that air bags designed to the lower standard would provide a similar range of performance over a similar range of speeds as was found for the existing fleet designed to the higher standard. By contrast the Alliance opportunities matrix model is based solely on an assumption that a theoretical bell-shaped relationship exists between proximity to the design point and effectiveness. No real world data or crash test data were provided or evaluated to demonstrate the validity of this construct.

Issue 5: The Alliance states that NHTSA developed effectiveness estimates for a population of MAIS 3+ injuries, but then erroneously applied them to fatalities because the crash distribution of fatalities is different from that of injuries.

Because of the limited sample size in NASS-CDS for fatalities, NHTSA did use MAIS 3+ injuries to develop the relative effectiveness of air bags for different delta-V levels, but these numbers were then normalized to the previously determined effectiveness rate for fatalities (Kahane). We also used AIS 2-5 injuries to represent injuries. The injury curve and effectiveness estimates are different between fatalities and injuries (See Chapter VI).

Issue 6: The Alliance states that NHTSA's Approach #2 assumes that injury criteria are related on a multiplicative basis across the whole range of crash severity, and that the agency assumes that all air bags designed to 25 mph will have injury criteria twice the level of 30 mph systems, no matter what the impact speed.

The Alliance misunderstood NHTSA's second approach which compared theoretical air bags designed to 25 mph and 30 mph. At this stage only pre-MY 1998 air bags have established a well known and stable performance which served as the baseline in the PEA analysis. Thus, all the test results were transformed to the equivalents of 30 mph. In addition, the Alliance ignored the statement on page VI-53 that air bags redesigned to the 25 mph tests were assumed to have the same compliance margin as those designed to 30 mph tests. The PEA's second approach analysis also assumed that air bags designed to 25 mph RFB have injury values proportionally higher than those designed to 30 mph RFB if tested in a given high impact speed. The proportion was derived by comparing test results and their compliance margins. The increased risks then were applied only to those fatalities which occurred with impact speeds above 25 mph or 30 mph. In other words, the PEA assumed the injury outcomes would be similar between these two air bag systems in a lower speed crashes (<25 mph). It is clear that the PEA's second approach did not assume injury values for 25 mph air bags are twice as high as the level of '30 mph' systems and did not disregard the crash severity as claimed by the Alliance.

Issue 7: The Alliance claims that the PEA ignores or understates the benefits from the high-speed OOP population and cites an IIHS study as indicative of these benefits.

The agency will address the Insurance Institute for Highway Safety (IIHS) comments on this topic later in this appendix.

Issue 8: The Alliance states that NASS derived delta-V, which was used in the PEA to estimate effectiveness by speed levels, is inaccurate or understated. The Alliance cites SAE papers that document inaccuracies in the NASS measurements.

NHTSA acknowledges that there may be inaccuracies in NASS delta-V estimates. However, NASS provides the best available estimates of delta V in crashes. They are based on detailed crash reconstruction and crash severity models. The entire world's technical community uses these estimates and methodology, including the Alliance in their two alternative methodologies presented (the MADYMO model and the Opportunities Matrix). It should be noted that if CDS underestimated the delta V, more fatalities and MAIS 3+ injuries would occur in a higher crash severity levels. This means that air bags passing 25 mph RFB might be designed to a smaller population than currently estimated, with a corresponding decrease in benefits.

Issue 9: The Alliance states that the PEA did not acknowledge or consider the ramifications of the fact that nearly half of all NASS cases did not have delta-V information.

The PEA acknowledges the high unknown delta V coded in the CDS. In response, multi-year CDS (1993-1997) data were used to reduce sample variation and increase the reliability of delta V distributions.

Issue 10: The Alliance criticized the PEA's use of total delta-V because it biases the distribution to higher delta-Vs. The Alliance stated that NHTSA should use longitudinal delta-V to avoid skewing the crash distribution to higher severity levels.

NHTSA disagrees with the Alliance conclusion that longitudinal delta-V should be used. Injury profiles are affected by total delta-V, not just longitudinal delta-V. For this reason NHTSA has consistently used total delta-V to measure safety benefits. Longitudinal delta-V is the appropriate measure when predicting air bag deployment levels, but not for injury severity categories.

Issue 11: The Alliance stated that delta-V should be tabulated only for air bag-equipped vehicles because the baseline target population is restricted to a fully air bag-equipped fleet of vehicles. The Alliance supplied a chart (Figure 7) to demonstrate the difference in injury distribution of air bag equipped and non-equipped vehicles.

NHTSA disagrees with this argument. In the table the Alliance is referring to (Table VI-28), the baseline target population developed is for unrestrained occupants in a fleet of vehicles without air bags. Then, the effectiveness of air bags can be applied to that target population. Because of the small sample size of fatalities with known delta-v, NHTSA used all vehicles to produce a more reliable estimate of the distribution of fatalities by delta V.

Issue 12: The Alliance claimed that NHTSA misapplied the FARS "Impact Point" variable when selecting cases for inclusion in frontal crashes. The alliance stated that this variable records the point of impact, but not the direction of impact, and that this results in the inclusion of too many cases in the target population.

Impact point is the only variable available in FARS to determine crash direction categories. There is no "direction of force" data available in FARS. It is standard procedure to use the FARs impact point variable to determine crash direction both within NHTSA studies and in studies by outside organizations such as IIHS. While this may not be a perfect measure, the important point is that the effectiveness rate used by NHTSA (Kahane) is based on this same FARS definition. In order to apply this rate, the target population must match the basis for the rate. If a narrower target population were used, the effectiveness rate would be proportionately higher.

Issue 13: The Alliance stated that NHTSA misinterprets the CDS variable "Principal Direction of Force" and that its use results in the inclusion of cases that strike from the a frontal direction but hit the vehicle in a non-frontal area that would not deploy the air bag.

NHTSA agrees that a small number of such cases could be included under the current definition of frontal used in the SNPRM. In response, the Agency has recalculated injuries in frontal impacts under a new definition that excludes all non-frontal impacts. It should be noted that this had only a minor impact on the estimate of nonfatal injury target population.

Issue 14: The Alliance states that the NASS CDS target population only represents 82 percent of police-reported deployment crashes, since 18 percent of GES deployments are in non-towaway crashes. Consequently, they state that the extent of the "at-risk" population in Table II-13 is understated.

The estimates of injuries in Table II-13 were derived from a census of all fatal cases where death was caused by air bags in crashes with delta-V less than 25 mph. NHTSA took the ratio of injuries/fatalities for those cases where the air bag was the source of injury from CDS and applied this ratio to total fatalities to estimate injuries caused by the air bag. The critical element in this definition is not deployments, but rather air bags as the source of injury. There is no reason to believe that the two vary proportionally. Moreover, GES does not contain the AIS codes needed to stratify injuries by severity. CDS is the only source for this data.

Issue 15: The Alliance states that the broad FARS and NASS target populations used in the PEA tend to encompass the wide range of impacts in which air bags may deploy, but is too broad for accurate consideration of air bag effectiveness. The Alliance recommends that NHTSA narrow the target populations to include only deployment impacts where air bag effectiveness is expected to improve.

NHTSA agrees that the range of injuries encompassed by the target population should match the effectiveness rates applied to that population. The PEA uses an effectiveness rate that represents the impact of air bags in all frontal crashes (derived from Kahane). Therefore, the target population is appropriate for the effectiveness rate used in the PEA.

Issue 16: The Alliance developed a theoretical assessment of the relative impact of various requirements using an opportunities matrix and a conceptual model of the impact of design changes. The Alliance concluded that the 30 mph RFB test with both 50^{th} male and 5^{th} female dummies provides 23% more benefit than this same test with just a 50^{th} male dummy, and that the 25 mph RFB test is 21% better than the 30 mph test.

The Alliance model is an interesting theoretical construct, but since it is entirely assumptive and not based on real world data, its findings are of limited use. One major weakness of the model is that, in essence, it assigns benefits based only on patterns of relative incidence. It does not address the issue of effectiveness per-se, but just assumes benefits will fall to occupants in different categories in a roughly bell-shaped pattern around the design point. The real world crash data used in the PEA contradict the Alliance's assumptive model and produces contrasting conclusions.

The agency used the most current crash data base to perform its safety related analysis. The agency believes that using the most current real-world crash data produces a more accurate assessment of current safety countermeasure systems and potential target populations for improvement.

Issue 17: The Alliance provided the results of a conceptual analysis using a MADYMO simulation to determine both the relative impact of different test requirements, and to estimate the compliance ability of various combinations of models of air bag design characteristics. In a meeting on January 14, 2000, Ford Motor Company provided NHTSA with a briefing on the MADYMO model (See Docket 1999-6407-95) . The focus of the meeting was on the assumptions used in the model and the results. Ford provided a submission to the docket showing the presentation materials and additional analyses. At the request of NHTSA, Ford also provided Nij data for the specific cases analyzed in their model. The mathematical analysis is very extensive and has a substantial number of assumptions involved. Starting with a mid-size passenger car and a dual-stage driver air bag, four air bag parameters (vents size, bag size, Stage 1 inflator, and Stage 2 inflator) are changed resulting in 336 different air bag designs. The power of the air bag is a variable, yet the most powerful Stage 1 and 2 combined system is not quite as powerful as the current redesigned air bags.

The first stage of Ford's analysis was to determine whether these designs would pass a group of tests which include: the 25 mph belted 5th female offset test, the 35 mph belted 50th male NCAP test, out-of-position tests for both the 5th female and 50th male driver, and unbelted 208 type tests for the 5th female and 50th male dummies at 25 and 30 mph. The out-of-position test for the 50th male dummy was not proposed in the SNPRM. The criteria for passing these tests include the dummy measurements and do include one injury measurement (neck shear), which was not proposed in the SNPRM. A 20 percent compliance margin is included for those injury criteria proposed in the SNPRM and typically a 10 percent compliance margin for other injury criteria. The higher speed portions of the model were validated using 7 existing tests including tests at 30 and 35 mph with the 5th and 50th dummies with the rigid barrier and the 40% offset test. No tests were run at lower speeds to validate the model at low speeds. The results of the first stage of the MADYMO analysis were a finding that 21 of 336 designs comply with a 25 mph unbelted set of tests, but none of the 336 designs comply with a 30 mph unbelted set of tests. The closest acceptance factor in the 30 mph unbelted test was 107 percent, indicating that the closest design was 7 percent above acceptable. A 100 percent acceptance factor includes either the 10 or 20 percent compliance margin depending upon the test and injury measure. Since their lowest acceptable compliance margin is 10 percent, at least one design (the one at 107 percent) passed all criteria.

The second stage of the process was to estimate the aggregate AIS 3+ occupant risk using the air bag designs that performed the best in the cadre of tests including the 25 mph and 30 mph unbelted tests. A separate set of assumptions is needed for this task. Ford's assumptions include an involvement frequency by delta V for 12 o'clock distributed impacts based on NASS 1988-96 for AIS 3+ injuries, the assumption that rigid barrier tests represent 30 percent of AIS 3+ injuries and a generic sled-type test would represent 70 percent, that the usage of seat belts decreases as delta V increases, that the 50th male dummy represents 60 percent of injuries while the 5th female dummy represents 40 percent of injuries, that dummy measurements are translated into injuries using an AIS 3+ injury curve for each injury criteria examined, and that the risk of fatality can be estimated using the 3 highest injuries derived from the AIS 3+ injury curve.

The model is an attempt to determine whether the net gains are positive or negative. Ford's results are:

1) For out-of position occupants, a 25 mph air bag would reduce AIS 3+ injury risk by about 50 percent.

2) For in-position occupants, a 25 mph air bag would reduce AIS 3+ injury risk by about 33 percent and overall fatality risk by about 50 percent.

The agency disagrees with several of the assumptions used in the model, including:

1) The selected best design representing the 30 mph air bag design does not meet the final rule criteria because the Nij for the 5th percentile female dummy is over 1.0. The 25 mph air bag does not appear to be a minimal design, it easily passes the criteria at 25 mph. Thus, in our opinion these designs do not represent a valid comparison of a vehicle designed to a 25 mph unbelted standard versus a vehicle designed to a 30 mph unbelted standard. The MADYMO model does not examine other aspects of air bag design, e.g. fold pattern, shape, tethering, seam pattern.

2) Air bags with more power should have been examined, at least to today's level of redesigned air bags.

3) Determining the validity of the model at lower speeds is a critical factor, which was not done.

4) The methodology for determining the impact on fatality risk is different from NHTSA's methodology. We believe fatalities have to be examined separately starting with the distribution of fatalities by delta V, using an AIS 5+ injury curve to estimate the risk of fatality using the dummy measurements. In addition, the 1980 NHTSA data Ford relied upon to determine risk of fatality from the three highest AIS injuries is old (MAIS injury codes have changed some over time). Using old data would have a minor impact on the conclusions.

5) The 5th percentile female dummy does not represent 40 percent of the injuries. NHTSA's analysis of 1993-97 CDS data indicates that the 5th percentile female represents only 21 percent of injuries, roughly half that assumed in Ford's model.

6) NHTSA disagrees with the percent of crashes assumed by Ford to be represented by the rigid barrier and generic sled pulse. Table V-2 in the FEA indicates that 78% of crashes are represented by the rigid barrier tests and 22% are represented by the generic sled test.

7) The agency also notes that the criteria examined in the MADYMO study exceed those proposed in the SNPRM. It is thus unclear how many of the 336 designs would pass the SNPRM proposals. NHTSA notes that at least one vehicle tested by the agency, the Saturn, did pass all of the high speed test requirements proposed in the SNPRM.

We took the raw data from the Ford MADYMO model for the 25 mph and 30 mph selected models (HIC, Nij, chest g's, chest deflection) and analyzed it using NHTSA's assumptions. However, we are still concerned that the selected 30 mph design did not meet the Nij criteria with the 5th percentile female dummy. Tables B-1 and B-2 show the raw data from Ford plus the calculated CTI value. Figures B-1 and B-2 show these data graphically. Examining the graphs and comparing the 25 mph air bag results to the 30 mph air bag results, we observe that:

1) For the HIC 15 curve for the 5th percentile female, sometimes the 25 mph air bag gives higher numbers, but usually the 30 mph air bag gives higher numbers. All of the HIC values are very low, with no estimated probability of fatality.

2) For the HIC 15 curve for the 50th percentile male, the 25 mph air bag usually gives higher numbers than the 30 mph air bag. There is a difference in higher speeds in the rigid barrier test.

3) The Nij curves for the 5th percentile female are unusual. Considering that only the Stage 1 inflator is used for the 5th percentile female at all speeds, it seems strange that the Nij would increase and decrease dramatically with increasing speeds. This suggests that the Nij level is more dependent upon the interaction of the dummy and air bag, than on the test speed.

4) The Nij curves for the 50^{th} percentile male intertwine at various speeds and are close together throughout. Unlike the 5^{th} percentile female Nij, curve, the 50^{th} percentile male Nij curves increase as test speed increases.

5) The CTI curves always show higher values with the 25 mph air bag than with the 30 mph air bag. Similarly, chest deflection and chest g's curves show higher values with the 25 mph air bag.

Tables B-3 through B-6 provide the results of NHTSA's analysis using the Ford MADYMO raw data. Each speed from the Ford model was assumed to represent a range of speeds around that point. For instance, the results at 10 mph were assumed to represent the results from 8 to 12 mph. The percent of occupants is taken from unbelted occupants in NASS. Since we are examining the results of two unbelted tests (25 mph vs. 30 mph), no belt use was assumed. Using NHTSA's probability of injury curves, a probability of fatality from the AIS 5+ curve or a probability of AIS 3+ injury from the AIS 3+ curve was determined for HIC, Nij, and CTI for 50^{th} males, 5^{th} females and in both rigid and generic tests. At this point, two separate analyses were performed using different assumptions. In Tables B-3 and B-4, the distribution of injuries by body region for unbelted adult front-outboard occupants at all severity levels with no air bag (as shown in Table B-5) was used to determine a combined probability of fatality or AIS 3+ injury. These are then weighted by male/female and rigid/generic test type to provide a total weighted probability of fatality or injury. Overall, weighted by speed, for fatalities there was no difference between the 25 mph air bag design and the 30 mph air bag design. For AIS 3+ injuries, the probability of injury was 1.63 percent with a 25 mph air bag design and 0.96 percent with a 30 mph air bag design, a 69 percent reduction. This large of a difference seems unlikely.

For Tables B-6 and B-7, occupant injuries were not weighted by body region using data from NASS, but they are combined using the formula shown on Page VI-15. This method allows neck injury to have a larger influence on the final results, and the 5th percentile female Nij estimates from the MADYMO model have a strong influence on the results. The probability of fatality was 2.93 percent with a 25 mph air bag design and 3.02 percent with a 30 mph air bag design, an increase of 2.91 percent. For AIS 3+ injuries, the probability of injury was 10.31 percent with a 25 mph air bag design and 9.15 percent with a 30 mph air bag design, a 12.7 percent reduction.

In conclusion, the agency doesn't believe it has a valid comparison using the selected air bag designs from Ford representing a 25 mph air bag and a 30 mph air bag for two reasons. First, there is no guarantee that the 25 mph air bag is a minimal design that just meets the 25 mph standard. An examination of Table B-1 for the rigid type impact show all dummy measurements well below the injury criteria at 40 kph (25 mph), even well below a 20 percent compliance margin. Thus, it represents a relatively good 25 mph air bag, one that meets all of the injury criteria at 30 mph (although no one would certify an air bag at 59.33 chest g's). Second, the 30 mph air bag design does not pass the Nij criteria for the 5th percentile female dummy. The 5th percentile female dummy Nij results have a significant influence on the overall results of the analysis. Nonetheless, the agency used its own analysis procedures with the raw data from the MADYMO model and finds results that are significantly different than Ford's results. Ford found that the 25 mph air bag design significantly decreased the risk of fatality (50 percent) and injury (33 percent) compared to a 30 mph air bag design for in-position occupants. NHTSA's analysis of the same raw data, finds the same, or nearly the same, fatality risk between the two air bag designs and a 13 to 69 percent increase in AIS 3+ (serious injury and fatality) risk for the 25 mph air bag design compared to the 30 mph design.

The Alliance MADYMO model is an interesting theoretical construct, but since it is somewhat assumptive and not totally based on real world data, and it does not include designs that totally meet the final rule, its findings are of limited use. The agency's analysis of this information does not agree with Ford's conclusion that an air bag designed to a 25 mph unbelted test will provide more protection than an air bag designed to a 30 mph unbelted test, but shows the opposite.

Table B-1
Rigid Type Impact

50th Percentile Male

Selected 25 mph Design

Test Speed (kph)	Head HIC 15	Neck Nij	Chest g's	Chest Deflection mm	CTI
16	1.01	0.15	5.37	4.68	0.11
24	84.60	0.30	22.71	18.11	0.43
32	94.47	0.34	26.74	24.06	0.53
40	135.67	0.35	43.47	28.93	0.76
48	470.14	0.71	59.33	35.32	1.00
56	624.91	0.60	59.43	56.54	1.21

Selected 30 mph Design

16	1.01	0.15	5.37	4.68	0.11
24	36.33	0.31	18.18	20.37	0.40
32	46.23	0.29	20.20	21.55	0.43
40	115.48	0.43	33.21	26.31	0.62
48	217.19	0.51	47.55	35.29	0.87
56	485.51	0.69	49.12	39.18	0.93

5th Percentile Female

Selected 25 mph Design

Test Speed (kph)	Head HIC 15	Neck Nij	Chest g's	Chest Deflection mm	CTI
16	87.96	0.28	13.04	24.53	0.44
24	158.13	0.78	27.11	26.43	0.62
32	146.72	0.41	29.90	29.39	0.68
40	183.51	0.53	33.33	31.74	0.75
48	153.66	0.61	40.92	49.22	1.04
56	284.07	1.28	51.79	53.54	1.21

Selected 30 mph Design

16	87.98	0.28	13.04	24.53	0.44
24	162.32	0.75	26.14	22.61	0.56
32	209.34	0.86	27.63	23.25	0.58
40	236.87	1.17	30.53	27.63	0.67
48	159.55	0.53	32.31	32.85	0.75
56	176.34	0.51	46.40	43.00	1.03

Table B-2
Generic Type Impact

50th Percentile Male

Selected 25 mph Design

Test Speed (kph)	Head HIC 15	Neck Nij	Chest g's	Chest Deflection mm	CTI
16	0.69	0.09	5..35	0.01	0.06
24	38.37	0.38	20.18	25.32	0.47
32	103.53	0.48	23.49	20.68	0.46
40	100.66	0.33	27.85	24.34	0.55
48	110.92	0.39	31.56	26.44	0.61
56	140.64	0.57	46.13	30.64	0.81

Selected 30 mph Design

16	0.69	0.09	5.35	0.01	0.06
24	38.13	0.38	20.22	25.23	0.47
32	48.65	0.31	20.03	20.02	0.42
40	51.50	0.33	22.06	20.38	0.44
48	77.45	0.35	29.57	22.03	0.54
56	181.18	0.40	41.17	28.80	0.74

5th Percentile Female

Selected 25 mph Design

Test Speed (kph)	Head HIC 15	Neck Nij	Chest g's	Chest Deflection mm	CTI
16	86.97	0.27	12.25	22.55	0.40
24	75.79	0.35	20.71	34.93	0.65
32	150.53	0.73	26.79	28.59	0.64
40	194.72	1.37	29.74	31.10	0.70
48	198.54	1.32	30.96	33.42	0.74
56	205.33	1.04	32.65	36.37	0.80

Selected 30 mph Design

16	86.96	0.27	12.25	22.55	0.40
24	75.78	0.35	20.70	34.93	0.65
32	265.84	1.61	26.27	24.88	0.59
40	238.53	1.22	28.95	25.81	0.63
48	257.13	1.36	31.54	26.75	0.67
56	289.66	1.48	34.79	29.13	0.73

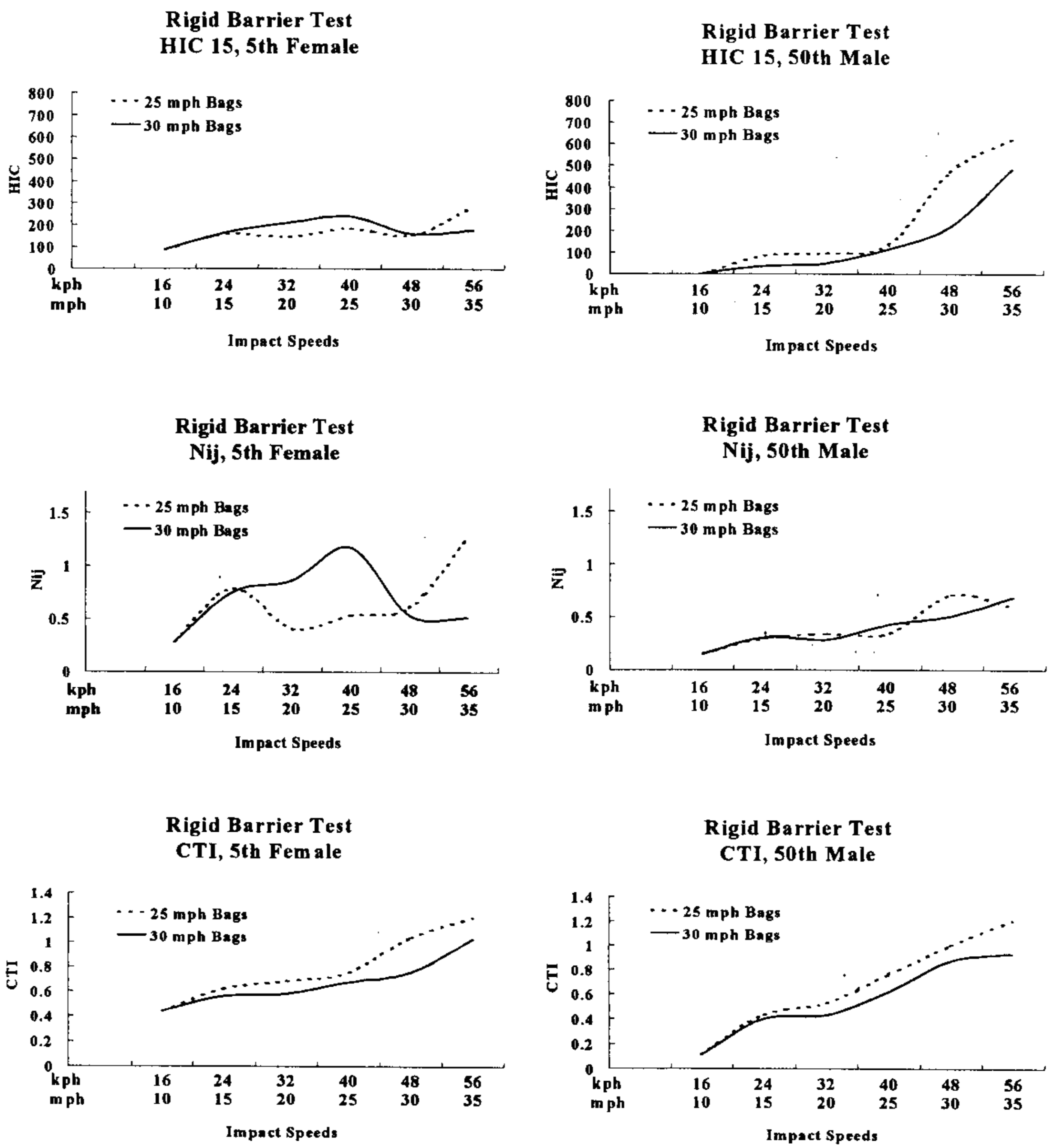

Figure B-1 Head, Neck, and Chest Injury Values, Rigid Barrier Tests Fords' MADYMO Simulation Data

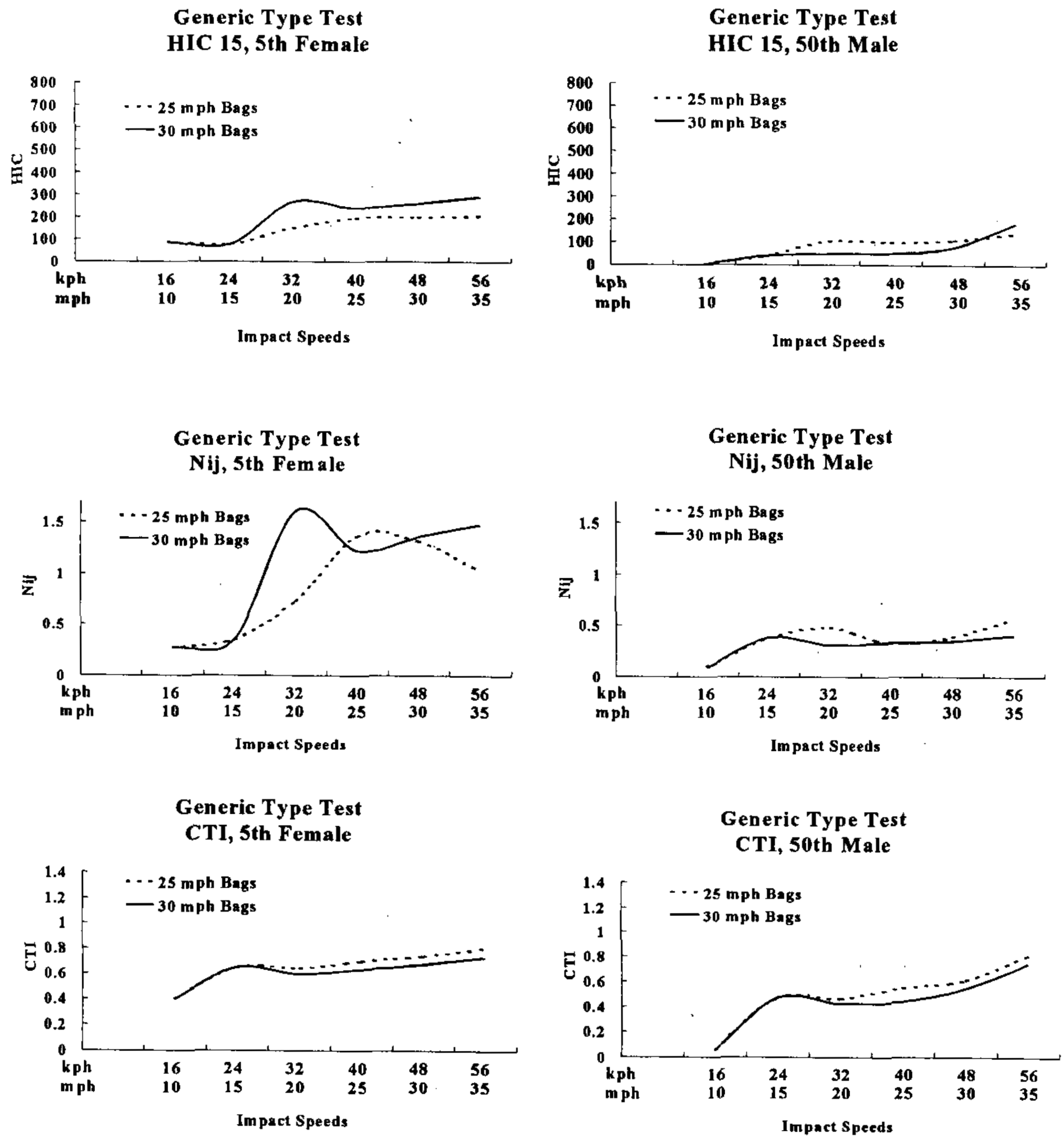

Figure B-2 Head, Neck, and Chest Injury Values, Generic Type Tests Fords' MADYMO Simulation Data

Table B-3
Fatality Risk Probabilities
25 MPH Bags vs 30 MPH Bags

Combined Probabilities Were Weighted by Crash Severity, Crash Type, Occupant Status , and Injured Body Region

25 MPH Bags											
			Combined Probability of Fatalities**				Weighted Combined Probability of Fatalities				
Speed		% of* Occupants	Rigid Barrier Tests		Generic Tests		Rigid Barrier Tests		Generic Tests		Total***
kph	mph		50th Male	5th Female	50th Male	5th Female	50th Male	5th Female	50th Male	5th Female	
13-20	8-12	26.38%	0.07%	0.08%	0.06%	0.08%	0.02%	0.02%	0.02%	0.02%	0.02%
21-28	13-17	35.05%	0.14%	0.24%	0.15%	0.15%	0.05%	0.08%	0.05%	0.05%	0.06%
29-36	18-22	15.95%	0.08%	0.08%	0.09%	0.12%	0.01%	0.01%	0.01%	0.02%	0.01%
37-44	23-27	5.44%	0.04%	0.05%	0.04%	0.12%	0.00%	0.00%	0.00%	0.01%	0.00%
45-52	28-32	3.08%	0.34%	0.29%	0.23%	0.64%	0.01%	0.01%	0.01%	0.02%	0.01%
53+	33+	2.35%	0.35%	0.64%	0.27%	0.45%	0.01%	0.02%	0.01%	0.01%	0.01%
Total risk probability for all speeds							**0.10%**	**0.14%**	**0.10%**	**0.13%**	**0.11%**
30 MPH Bags											
13-20	8-12	26.38%	0.07%	0.08%	0.06%	0.08%	0.02%	0.02%	0.02%	0.02%	0.02%
21-28	13-17	35.05%	0.14%	0.23%	0.15%	0.15%	0.05%	0.08%	0.05%	0.05%	0.06%
29-36	18-22	15.95%	0.07%	0.14%	0.07%	0.31%	0.01%	0.02%	0.01%	0.05%	0.01%
37-44	23-27	5.44%	0.04%	0.09%	0.04%	0.10%	0.00%	0.01%	0.00%	0.01%	0.00%
45-52	28-32	3.08%	0.26%	0.27%	0.22%	0.67%	0.01%	0.01%	0.01%	0.02%	0.01%
53+	33+	2.35%	0.32%	0.26%	0.22%	0.72%	0.01%	0.01%	0.01%	0.02%	0.01%
Total risk probability for all speeds							**0.10%**	**0.14%**	**0.10%**	**0.16%**	**0.11%**
Compared to the 30 mph bags, 25 mph bags increase risk of fatalities for unbelted Occupants by											**0.00%**

* Unbelted adult front-outboard occupants in frontal crashes with no air bags
** Weighted head, neck, and chest risk probabilities
*** Weighted by crash severity (delta v) , crash type (rigid, generic), and occupant status (50^{th} male, 5^{th} female)
Source: 1993-1998 NASS CDS, Ford's MADYMO simulation data

Table B-4
MAIS3+ Injury Risk Probabilities
25 MPH Bags vs 30 MPH Bags

Combined Probabilities Were Weighted by Crash Severity, Crash Type, Occupant Status , and Injured Body Region

25 MPH Bags											
			Combined Probability of AIS3+ Injuries**				**Weighted Combined Probability of AIS3+ Injuries**				
Speed		**% of* Occupants**	**Rigid Barrier Tests**		**Generic Tests**		**Rigid Barrier Tests**		**Generic Tests**		**Total*****
kph	**mph**		**50th Male**	**5th Female**	**50th Male**	**5th Female**	**50th Male**	**5th Female**	**50th Male**	**5th Female**	
13-20	8-12	26.38%	0.14%	0.63%	0.12%	0.57%	0.04%	0.17%	0.03%	0.15%	0.06%
21-28	13-17	35.05%	0.76%	2.11%	0.39%	0.63%	0.27%	0.74%	0.14%	0.22%	0.32%
29-36	18-22	15.95%	0.82%	1.87%	0.95%	1.91%	0.13%	0.30%	0.15%	0.31%	0.17%
37-44	23-27	5.44%	2.40%	2.08%	0.69%	2.41%	0.13%	0.11%	0.04%	0.13%	0.11%
45-52	28-32	3.08%	18.51%	4.38%	1.64%	4.35%	0.57%	0.13%	0.05%	0.13%	0.39%
53+	33+	2.35%	31.74%	24.82%	4.78%	4.96%	0.75%	0.58%	0.11%	0.12%	0.58%
Total risk probability for all speeds							**1.88%**	**2.03%**	**0.52%**	**1.06%**	**1.63%**
30 MPH Bags											
13-20	8-12	26.38%	0.14%	0.63%	0.12%	0.57%	0.04%	0.17%	0.03%	0.15%	0.06%
21-28	13-17	35.05%	0.36%	2.13%	0.39%	0.63%	0.13%	0.75%	0.14%	0.22%	0.23%
29-36	18-22	15.95%	0.29%	3.27%	0.29%	4.63%	0.05%	0.52%	0.05%	0.74%	0.16%
37-44	23-27	5.44%	1.24%	3.00%	0.23%	2.81%	0.07%	0.16%	0.01%	0.15%	0.08%
45-52	28-32	3.08%	5.84%	2.51%	1.20%	5.12%	0.18%	0.08%	0.04%	0.16%	0.14%
53+	33+	2.35%	15.90%	12.48%	3.34%	5.83%	0.37%	0.29%	0.08%	0.14%	0.30%
Total risk probability for all speeds							**0.83%**	**1.97%**	**0.34%**	**1.56%**	**0.96%**
Compared to the 30 mph bags, 25 mph bags increase risk of AIS3+ Injuries for unbelted Occupants by											**69.00%**

* Unbelted adult front-outboard occupants in frontal crashes with no air bags
** Weighted head, neck, and chest risk probabilities
*** Weighted by crash severity (delta v) , crash type (rigid, generic), and occupant status (50th male, 5th female)
Source: 1993-1998 NASS CDS, Ford's MADYMO simulation data

Table B-5

Weighting Factors for Injured Body Region

Speed		Percent of Unbelted Front-Outboard Occupants in Vehicles with No Air Bags by Crash Impact Speeds		
kph	mph	Head	Neck	Chest
13-20	8-12	65%	3%	5%
21-28	13-17	66%	5%	3%
29-36	18-22	78%	2%	6%
37-44	23-27	59%	1%	9%
45-52	28-32	63%	7%	5%
53+	33+	34%	6%	34%

Source: 1993-1998 NASS CDS

Table B-6
Fatality Risk Probabilities
25 MPH Bags vs 30 MPH Bags

Combined Probabilities Were Weighted by Crash Severity, Crash Type, and Occupant Status

25 MPH Bags											
			Combined Probability of Fatalities**				**Weighted Combined Probability of Fatalities**				
Speed		**% of* Occupants**	**Rigid Barrier Tests**		**Generic Tests**		**Rigid Barrier Tests**		**Generic Tests**		**Total*****
kph	**mph**		**50th Male**	**5th Female**	**50th Male**	**5th Female**	**50th Male**	**5th Female**	**50th Male**	**5th Female**	
13-20	8-12	26.38%	2.57%	2.98%	2.39%	2.95%	0.68%	0.79%	0.63%	0.78%	0.69%
21-28	13-17	35.05%	3.05%	5.30%	3.35%	3.24%	1.07%	1.86%	1.17%	1.14%	1.22%
29-36	18-22	15.95%	3.20%	3.47%	3.76%	5.01%	0.51%	0.55%	0.60%	0.80%	0.55%
37-44	23-27	5.44%	3.25%	3.99%	3.16%	10.17%	0.18%	0.22%	0.17%	0.55%	0.20%
45-52	28-32	3.08%	4.96%	4.42%	3.39%	9.64%	0.15%	0.14%	0.10%	0.30%	0.15%
53+	33+	2.35%	4.54%	9.40%	4.18%	7.10%	0.11%	0.22%	0.10%	0.17%	0.13%
Total risk probability for all speeds							**2.69%**	**3.77%**	**2.78%**	**3.73%**	**2.93%**
30 MPH Bags											
13-20	8-12	26.38%	2.57%	2.98%	2.39%	2.95%	0.68%	0.79%	0.63%	0.78%	0.69%
21-28	13-17	35.05%	3.09%	5.12%	3.35%	3.24%	1.08%	1.79%	1.17%	1.14%	1.22%
29-36	18-22	15.95%	3.02%	5.80%	3.09%	13.11%	0.48%	0.92%	0.49%	2.09%	0.63%
37-44	23-27	5.44%	3.55%	8.19%	3.16%	8.65%	0.19%	0.45%	0.17%	0.47%	0.24%
45-52	28-32	3.08%	3.91%	3.99%	3.24%	10.06%	0.12%	0.12%	0.10%	0.31%	0.13%
53+	33+	2.35%	4.83%	3.95%	3.44%	11.44%	0.11%	0.09%	0.08%	0.27%	0.11%
Total risk probability for all speeds							**2.67%**	**4.17%**	**2.65%**	**5.05%**	**3.02%**
Compared to the 30 mph bags, 25 mph bags increase risk of fatalities for unbelted Occupants by											**-2.91%#**

* Unbelted adult front-outboard occupants in frontal crashes with no air bags
** Combined head, neck, and chest risk probabilities
*** Weighted by crash severity (delta v), crash type (rigid, generic), and occupant status (50th male, 5th female)
# Note that the agency does not believe this is a valid comparison of a 25 mph air bag and a 30 mph air bag, since the 25 mph air bag easily meets the injury criteria at 25 mph, but the 30 mph air bag does not meet the Nij requirements. Differences in Nij account for this result.
Source: 1993-1998 NASS CDS, Ford's MADYMO simulation data

Table B-7
MAIS3+ Injury Risk Probabilities
25 MPH Bags vs 30 MPH Bags

Combined Probabilities Were Weighted by Crash Severity, Crash Type, and Occupant Status

25 MPH Bags											
			Combined Probability of AIS3+ Injuries**				**Weighted Combined Probability of AIS3+ Injuries**				
Speed		**% of* Occupants**	**Rigid Barrier Tests**		**Generic Tests**		**Rigid Barrier Tests**		**Generic Tests**		**Total*****
kph	**mph**		**50th Male**	**5th Female**	**50th Male**	**5th Female**	**50th Male**	**5th Female**	**50th Male**	**5th Female**	
13-20	8-12	26.38%	5.12%	7.61%	4.56%	7.31%	1.35%	2.01%	1.20%	1.93%	1.46%
21-28	13-17	35.05%	7.84%	19.06%	8.46%	10.05%	2.75%	6.68%	2.97%	3.52%	3.46%
29-36	18-22	15.95%	8.96%	12.94%	10.71%	17.97%	1.43%	2.06%	1.71%	2.87%	1.65%
37-44	23-27	5.44%	15.41%	17.02%	9.03%	41.16%	0.84%	0.93%	0.49%	2.24%	0.86%
45-52	28-32	3.08%	52.87%	41.06%	11.20%	39.91%	1.63%	1.26%	0.34%	1.23%	1.33%
53+	33+	2.35%	78.69%	76.09%	21.48%	31.35%	1.85%	1.79%	0.50%	0.74%	1.55%
Total risk probability for all speeds							**9.84%**	**14.73%**	**7.22%**	**12.52%**	**10.31%**
30 MPH Bags											
13-20	8-12	26.38%	5.12%	7.61%	4.56%	7.31%	1.35%	2.01%	1.20%	1.93%	1.46%
21-28	13-17	35.05%	7.29%	17.85%	8.46%	10.05%	2.56%	6.26%	2.97%	3.52%	3.28%
29-36	18-22	15.95%	7.24%	22.01%	7.41%	51.70%	1.15%	3.51%	1.18%	8.25%	1.87%
37-44	23-27	5.44%	11.96%	33.45%	7.79%	34.70%	0.65%	1.82%	0.42%	1.89%	0.86%
45-52	28-32	3.08%	26.35%	17.09%	9.45%	41.11%	0.81%	0.53%	0.29%	1.27%	0.70%
53+	33+	2.35%	49.20%	40.26%	15.62%	47.71%	1.16%	0.95%	0.37%	1.12%	0.98%
Total risk probability for all speeds							**7.68%**	**15.07%**	**6.43%**	**17.97%**	**9.15%**
Compared to the 30 mph bags, 25 mph bags increase risk of AIS3+ Injuries for unbelted Occupants by											**12.71%**

* Unbelted adult front-outboard occupants in frontal crashes with no air bags
** Combined head, neck, and chest risk probabilities
*** Weighted by crash severity (delta v) , crash type (rigid, generic), and occupant status (50^{th} male, 5^{th} female)
Source: 1993-1998 NASS CDS, Ford's MADYMO simulation data

B. Analyses of Crash Data

There were two comments to the docket about analyses of crash data regarding air bags.

1) The University of Michigan, Transportation Research Institute (UMTRI) (Docket No. 6407, #69) provided an analysis of 160 occupants (120 drivers and 40 right front seat passengers). Their conclusions are:

"... depowered airbags are equivalent to pre-depowered airbags in offering protection to both belt-restrained and unbelted front-seat passengers involved in moderate to severe frontal crashes. In addition , the database suggest that, for the most part, depowered airbags are significantly less aggressive during deployment than pre-depowered airbags. However, the data also show that depowered airbags can still cause serious or fatal injuries to child and adult occupants who are in close proximity to the airbag module at the time of deployment."

The UMTRI database did find one case of an unbelted occupant overpowering the depowered air bag. This driver was 6'7" tall, weighed 230 lbs., was involved in a 40-mph impact and suffered serious, but non-fatal injuries.

NHTSA response:

To date, NHTSA's data and findings agree with UMTRI's conclusions.

2) The Insurance Institute for Highway Safety (IIHS) (Docket No. 6407, #67) - IIHS made two claims that prompted the agency to do hard-copy analyses of NASS cases. The claims were:

First, that IIHS is unaware of any cases in which the energy of the deploying air bag was inadequate. Second, that their studies of air bag performance in moderate to severe frontal crashes shows that drivers are dying because of overwhelming intrusion that no air bag design can overcome, ejection, and injury from the air bag itself. IIHS estimates that about 15 percent of the cases they examined were caused by the air bag itself.

NHTSA response:

The agency examined every case of a driver or passenger fatality in NASS (from 1988 through the first six months of 1999) with air bags and known delta V over 25 mph (those under 25 mph are already examined in the Special Crash Investigation file). The selection criteria for the cases included a frontal impact with a known delta V of 25 mph and greater with no rollover and ejections. In addition, the two cases identified by IIHS as an air bag caused fatality with unknown delta V were examined. In all, 57 cases were clinically reviewed by NHTSA (excluding one case that was reviewed but turned out to be an ejection). The cases are summarized below:

37 cases were deemed unsurvivable, 33 from intrusion, 4 from insufficient occupant protection from the air bag/belt system in a high (greater than 40 mph delta V) crash

11 cases in which the air bag probably caused the fatality (one with a redesigned air bag). Ten were drivers and one passenger. The NASS year and case numbers are: [1991, 79-21A; 1993, 6-6A; 1993, 08-133A, 1994, 11-150A; 1995, 09-167A, 1996 08-100A, 1997 6-126 (passenger); 1997 72-103; 1997 82-186; 1998 9-87; 1998 43-88]

4 cases of insufficient occupant protection from the air bag/belt system (3 with heavy occupants) (one with a redesigned air bag). These crashes were deemed potentially survivable if the air bag had worked better, with little intrusion and delta V less than 40 mph. The case numbers are:

[1998, 2-154; 1998, 6-147; 1999, 6-38; 1999, 74-13 (redesigned)]

3 cases that had two causes of fatality, intrusion to the chest and the air bag to the head/neck. These people would have died with or without an air bag (one with a redesigned air bag). The case numbers are:

[1995, 5-125A; 1998, 9-144 (redesigned); 1998, 49-83]

1 non-deployment of the air bag

1 reclined passenger, out-of-position, died from injuries caused by the seat belt

A brief description of these 57 cases will be docketed in a paper entitled "A Summary of NASS Cases from 1989-1999 with Air Bag Related Fatalities or Insufficient Occupant Protection".

While the agency found that 11 of 57 cases examined (roughly 19 percent) were air bag caused fatalities, this does not mean that 19 percent of all remaining air bag deployment fatalities are caused by air bags. One has to consider the case selection criteria of only known delta V above 25 mph, no ejections and no rollovers.

To provide a national estimate based on these cases, we examined the latest two years (1997 and (1998) that had the highest number of air bag caused high speed fatalities. There were three air bag caused high speed fatalities in calendar year 1997 NASS and there were two air bag caused high speed fatalities in calendar year 1998 NASS. These numbers are so sparse that we can not make a reasonable prediction of the number of fatalities they represent nationwide. While NASS is a survey, and predictions can be made from the results, those numbers are hardly reliable from a sample of two or three cases.[4] However, we can be confident that they do not represent 15 percent of all remaining fatalities in air bag deployment cases.

Many of the 11 cases are in older model air bag cars. The model years are 1990 (1), 1991 (1), 1992 (4), 1993 (1), 1994 (1), 1995 (2), and 1996 (1). There have been many design changes in air bags over the years, which may reduce these numbers for later models.

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[4] The combined national weights of the three air bag related fatalities in 1997 NASS were 32.25. In 1997 NASS-CDS, there were 747.2 weighted fatalities in frontal crashes with deployed air bags. Of these 117.3 had a delta V of < 25 mph, 239.34 had a delta V > 25 mph, and 390.66 with unknown delta V. Distributing the unknowns would result in 501.37 with delta V greater than 25 mph. The following factor (501.37/239.24 = 2.1) is used to estimate the number of fatalities caused by air bags in crashes with delta V > 25 mph in 1997 = 32.25 X 2.1 = 68 (42 drivers and 26 passengers).

The combined national weights of the two air bag related fatalities in 1998 NASS were 77.32. In 1998 NASS-CDS, there were 1,757.68 weighted fatalities in frontal crashes with deployed air bags. Of these 122.03 had a delta V of < 25 mph, 603.88 had a delta V > 25 mph, and 1,031.86 with unknown delta V. Distributing the unknowns would result in 1.462.34 with delta V greater than 25 mph. The following factor (1,462.34/603.88 = 2.42) is used to estimate the number of fatalities caused by air bags in crashes with delta V > 25 mph in 1998 = 77.32 X 2.42 = 187 drivers and no passengers.

The next steps in the process are to determine how many air bag caused fatalities there would be in crashes with a delta V > 25 mph if there were a whole fleet of these pre-MY 1998 air bags. Taking the numbers above and dividing them by the portion of the fleet with air bags (see Table II-4) results in estimates of 257 in 1997 and 475 in 1998 fatalities caused by air bags per year in crashes with delta V greater than 25 mph if all vehicles on the road had air bags. Weighting these deaths over the two years gives an average of 367 occupants (303 drivers and 64 passengers). As shown in Table II-3, there are an estimated 15,725 frontal fatalities remaining with a full fleet of air bags. The estimated number of 367 is 2.3 percent of remaining fatalities, not the 15 percent that IIHS discusses.

Again please note that these estimates are not considered reliable.

We have found 4 cases in 1998 and 1999 NASS in which we believe the air bag was not strong enough, one with a redesigned air bag, and UMTRI found one such case. In general, these were cases where the occupant went over the top of the air bag, or hit the air bag off-center or on a corner of the air bag and was not contained by the air bag. Thus, we do not agree with IIHS that there is always sufficient force in the air bag. In fact, there were more high speed cases in this time frame (4 cases in 1998 and the first 6 months of 1999) in which there was insufficient occupant protection provided by the air bag than high speed cases (2 cases) in which there was too much power.

We note that the IIHS cases are predominantly cases of pre-MY 98 air bags causing a fatality in high speed, greater than 25 mph delta V crashes. However, we have also found 1 case of a redesigned air bag (Case # 1998, 9-144) that caused a fatal injury. This was one of the cases that had two causes of fatality, both the air bag and intrusion. Thus, the redesigned air bags did not solve all of the out-of-position problems in high speed crashes, just as they did not solve all of the out-of-position problems in lower speed crashes. There are not enough cases to make a projection of how effective redesigned air bags have been in high speed crashes where the occupant is out-of-position.

Finally, we have no data on how well vehicles designed to a 25 mph unbelted standard would perform in high speed crashes. We don't know whether a 25 mph air bag would reduce these air bag caused fatalities or not, particularly on the driver side, which has the most fatalities.

The agency has also identified an additional 12 instances of air bag caused fatalities in crashes with delta V above 25 mph. Eleven of these instances were initially investigated as SCI cases, but were dropped when it was determined that they were higher than 25 mph delta V. One case was investigated as part of the CIREN hospital study project. These 12 instances are not NASS cases, and do not add to the total preliminary estimate in footnote 4 a few pages earlier.

C. Analysis of Statement by IIHS to the Transportation Subcommittee, U.S. House of Representatives Appropriations Committee, February 10, 2000

ISSUE 1

IIHS disagrees with the NHTSA Approach 1 in estimating the potential loss in benefits of a 25 mph unbelted rigid barrier test versus a 30 mph unbelted rigid barrier test. IIHS argues that their detailed examination of individual NASS cases provides convincing evidence that the drop-off in the effectiveness estimates for higher crash severities have nothing to do with inadequate air bag performance. Instead, IIHS claims they are caused by intrusion, ejections, or by the air bags themselves. IIHS claims that NHTSA implicitly assumes that the drop-off in effectiveness shown in high speed cases (presumably delta V > 30 mph, since this was the highest group in Approach 1), is entirely due to insufficient energy absorption by air bags. IIHS argues that we ignore evidence and that our shifting of the effectiveness curve by 5 mph is "wholly unjustified". IIHS would argue that shifting the effectiveness curve by 5 mph ignores the fact that catastrophic crashes with intrusion are more highly represented in higher delta V crashes. In their opinion, these fatalities are unsurvivable with air bags and would be unaffected by changes in the energy absorbing characteristics of air bags.

NHTSA response:

The agency's analysis of fatalities in air bag vehicles in high speed cases (greater than 30 mph delta V) shows that more than 35 percent are not caused by ejection, intrusion at any level, or injury induced by the air bag.

The agency agrees that effectiveness decreases as delta V increases, partly because of the severe intrusion cases, and our analyses show this. But, severe intrusions[5] are only one piece of a complicated puzzle and severe intrusions only become a significant part of the fatality picture at crashes above 40 mph delta V (based on our estimates, severe intrusion is about 5 percent between 20 and 40 mph delta V and about 21 percent from 40 mph and higher). It is also true that ejections are a larger part of occupant fatalities in frontal crashes at lower speed than in the higher speed ranges and ejections are not typically savable by air bags. To examine this issue, the agency distributed cases without air bags into various cells: those that are theoretically savable by air bags because they exclusively involved occupant contacts with frontal interior surfaces with zero or less than 12 inches of intrusion; and those not savable by air bags because they involved ejections, contact with interior surfaces to the side or roof, and/or severe intrusion. Table B-8 shows this analysis for vehicles without air bags. These data include MY 1981-99 vehicles in NASS 1991-99, belted and unbelted occupants and include some cases that were run through a separate program to estimate delta V when the NASS file had no estimate of the delta V.

[5] Severe intrusion is defined as a case in which the interior component that caused the fatality intruded toward the occupant by 12 inches or more, as documented in the basic NASS-CDS data file.

Table B-8
Non Air Bag Vehicles in NASS 1991-99
Cause of Fatalities in Frontal Crashes by Delta V
(In Percent)

	0-20 mph (N = 61)	21-25 mph (N = 74)	26-30 mph (N = 66)	31-35 mph (N = 89)	36-40mph (N = 70)	41 + mph (N = 158)
No Intrusion	36	52	52	37	43	15
Less than 1 ft. of intrusion	7	4	12	27	26	21
Subtotal (Theoretically Savable by Air Bag)	43	56	64	64	69	36
Ejection	23	28	21	16	8	23
Severe Intrusion More than 1 ft.	0	4	5	7	14	21
Others	34*	12	10	13	9	20
Subtotal (Theoretically Not Savable by Air Bag)	57	44	36	36	31	64
Total	100	100	100	100	100	100

* This percentage for "Others" is higher in this speed cell than in higher speed cells because it includes fatalities that occurred below the deployment threshold. Also included in the "Others" category are fatal burns, non-frontal contacts, and A-pillar contacts.

The point we are trying to make with these data are that in the 30-40 mph speed ranges, severe intrusion crashes increase as delta V increases, however, ejections decrease as a proportion of fatalities in higher speed crashes. The percent of all frontal fatalities that are theoretically savable by air bags are about the same at all levels of speed until above 40 mph and these percentages are well above the percentage actually being saved by today's air bags of 15-30 percent. We see no overriding reason why we can't utilize our analysis of shifting delta V by 5 mph to estimate the impacts of the theoretical 25 mph air bags compared to 30 mph air bags.

In response to questions raised by IIHS, we recalculated effectiveness rates for each delta V category based only on crashes that are savable by the air bag. These modified rates were then applied only to the crashes that are savable by the air bag. Then, as before, we shifted the estimated effectiveness curve by delta V for those air bag savable cases, excluding those not savable which include severe intrusion, ejections, and others, down 5 mph and estimated the lives saved by the theoretical 25 mph air bags and compared them to the 30 mph air bags. This method eliminates the non-savable cases that IIHS argued would minimize effectiveness at higher delta V's compared to lower delta V's. The result shown in Table B-9 is an estimated larger number of lives lost under this methodology (-383 lives) for the theoretical 25 mph air bags compared to the 30 mph air bags, than under the methodology used in Chapter VI (-252 lives).

Table B-9
30 MPH Air Bags vs 25 MPH Air Bags

Delta V	Effectiveness (1)	Target Population(1)	% Savable	Savable Population(2)	Effectiveness Savable(3)	Lives Saved(4)
30 MPH Air Bags						
0-20	0.203	1966	0.43	845	0.472	399
21-25	0.290	2126	0.56	1,191	0.518	617
26-30	0.222	2228	0.64	1,426	0.347	495
31+	0.142	6361	0.51	3,244	0.278	902
Total						**2,413**
25 MPH Air Bags						
0-15		1148	0.22	253	0.472	119
16-20		818	0.55	450	0.518	233
21-25		2126	0.56	1,191	0.347	413
26+		8589	0.53	4,552	0.278	1,265
Total						**2,030**
Difference						**-383**

1. See Table VI-28
2. Savable Population = Target Population * % Savable
3. Effectiveness Savable = Effectiveness / % Savable
4. Lives Saved = Effectiveness Savable * Savable Population

The agency believes that the effectiveness of an air bag designed to a 25 mph unbelted test will not be as high as the effectiveness of an air bag designed to a 30 mph unbelted test in high speed crashes. Further, there were no data provided by IIHS or the industry to convince the agency to change this belief. In fact, the Madymo modeling data supplied by Ford (see Docket #6407-95) confirms our belief that vehicles designed to a 25 mph unbelted test will not provide as much benefit in high speed crashes as vehicles designed to a 30 mph unbelted test.

Air bags save lives; this is not disputed. Our effectiveness estimates, based on NASS data, shown in Approach 1, show that they are saving lives in both low speed and high speed crashes. The agency's argument is that some of those lives currently being saved by air bags in high speed crashes would not be saved if air bags only met a 25 mph unbelted standard.

There are further reasons why the agency believes that air bags designed to a 30 mph unbelted test will save more lives than air bags designed to a 25 mph unbelted test. We believe those killed by air bags are limited to those out-of-position at the time of deployment for two reasons: 1) in 20 or 25 mph in-position testing, the dummy measurements are so low with a 30 mph designed air bag that the probability of fatality is tiny. You are on the flat part of the AIS 5+ injury curves shown in Chapter III, and the possibility of reducing the probability of fatality with an air bag designed to 25 mph for in-position occupants is infinitesimal. 2) An examination of the remaining fatalities with air bag deployments indicate that the 30 mph designed air bags are working very well for in-position occupants in the types of crashes air bags are designed to work in. In other words, we aren't finding many non-ejected fatalities to occupants in low speed crashes, unless the occupant strikes non-frontal interior surfaces or is out-of-position at the time of the air bag deployment. In summary, we don't believe there is any fatality benefit for in-position occupants for 25 mph air bags compared to 30 mph air bags. The number of out-of-position occupants at high speed is uncertain and the benefits of a 25 mph air bag versus a 30 mph air bag for out-of-position occupants in high speed crashes are unproven.

ISSUE 2

IIHS argues that the assumptions used in Approach 2 are questionable because they are based on only two models and unbelted crash tests do not predict unbelted real world crashes.

NHTSA response:

The agency agrees that it only had data on two vehicles to use in Approach 2. The test results and dummy measurements from these two vehicles at 30 mph are in the middle of the larger set of vehicles tested at 30 mph, so they appear to be somewhat representative of the fleet. Finally, the results are consistent with the amount of energy in a 25 mph crash compared to a 30 mph crash. No additional data were provided by IIHS or the industry to rebut these findings.

The IIHS argument that unbelted crash tests do not predict unbelted real world crashes relies on their belief that many unbelted occupants are out-of-position at the time of air bag deployment and either are injured by the air bag or do not get the full protection of the air bag. We simply have not found many occupants killed by the air bag in high speed cases and the effectiveness we use is from real-world data that includes both cases where the air bag killed out-of-position occupants and cases where the air bag provided less than full protection. Thus, we disagreee with IIHS and believe the unbelted test results do provide a realistic estimate of unbelted occupant benefits.

D. Analysis of comments from DaimlerChrysler (99-6407-#44)

Appendix 2, page 4 of 5,

a) DaimlerChrysler notes that NHTSA has measured no significant difference in the frontal occupant crash protection between pre'98 MY and the '98-'99 MY vehicles with depowered air bags. They find it "perplexing" that the agency suggests a loss of benefits associated with a 40 km/h (25 mph) unbelted barrier test, when added to the cadre of other proposed test requirements. The agency states the sled test can be likened to a 22 mph rigid barrier test. "If vehicles certified to that test provide as much, if not more, overall protection than vehicles certified to the 30 mph (48 km/h) test, it is illogical to state that making that test requirement more stringent; i.e., raising it to 25 mph (40 km/h), will result in a loss of relative benefits."

NHTSA response:

The unbelted test is really the defining test in terms of the protectiveness of the air bag in high speed collisions. The other cadre of tests define other parameters of the system. Thus, benefits can be estimated based on whether the unbelted test is set at 25 mph or 30 mph. The agency believes that the MY 98/99 vehicles were not depowered as much as they could have been to meet the sled test. The agency believes the manufacturers didn't have enough design time to depower and optimize the air bags. Chrysler admits this in Appendix 5 on page 9 of 67 where they state that the depowered air bags were less-optimized, the only change was in the amount of gas generant, and no change was made to the air bag design to optimize the system. The amount of depowering was only about half as much as the agency thought was possible. Based on depowered air bag prototypes provided by the manufacturers, the agency thought the manufacturers could depower by 20 to 35 percent. However, confidential information supplied by the manufacturers in response to an information request indicated that the average amount of depowering was 16 percent. The low amount of depowering is shown by NHTSA testing. Most of the MY 98/99 vehicles tested were able to pass the 30 mph test with the 50^{th} percentile male dummy. If they had been depowered to the level of the sled test, the agency believes they would not pass the 30 mph test. The agency does estimate a larger disbenefit from the sled test than from the 25 mph barrier test (see Chapter VI), indicating its belief that the sled test is potentially a less severe test and closer to a 22 mph barrier test. These disbenefits were in comparison to pre-MY 98 air bags that were required to meet the 30 mph unbelted barrier test.

b) DaimlerChrysler stated that "... we do not believe it is sound science to use one test condition (full front rigid barrier tests), with a small sample of vehicles, and injury criteria which the agency itself has deleted from further consideration at this time as a regulatory measurement tool (CTI), to derive benefits to the whole fleet of vehicles in all types of crashes."

NHTSA response:

As discussed above, the unbelted test is the defining test of the strength of the air bag. The effectiveness of air bags meeting the 30 mph unbelted test (pre-MY 98) are taken from real world data analysis (Kahane) and estimated to be 11 percent in all types of crashes. Thus, there is a link between test data and real world effectiveness. The unbelted test results from a sample of vehicles are used to make benefits estimates for only unbelted fatalities, not all types of crashes. Whether the analysis uses chest g's and chest deflection separately, or uses the combined CTI does not matter in terms of estimating benefits. The CTI has the best correlation to injury.

Analytically it is easier to use one injury curve than two curves, and using the two curves would result in essentially the same benefit estimate as using the CTI.

c) DaimlerChrysler stated that "We are disappointed that the PEA fails to use the real-world findings from vehicles certified to the sled test as its baseline for its analysis, but instead chooses a limited number of laboratory tests. Actual field data should always take precedence over limited laboratory testing..."

NHTSA response:

We agree that field data should take precedence over laboratory testing. Our baseline is field data of pre-MY 98 vehicles, those certified to meet a 30 mph unbelted test. However, we do not agree that we have field data on vehicles designed to the minimum performance requirements of the sled test or vehicles designed to the minimum performance requirements of a 25 mph unbelted barrier test. Our testing shows that most of the MY 98/99 vehicles could meet the 30 mph unbelted test with the 50th percentile male dummy. Thus, the air bags in these vehicles were more protective than ones that could be designed to just meet a 25 mph unbelted barrier test and even more protective than ones that could be designed to just meet the sled test.

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a) DaimlerChrysler stated that NHTSA analysis of depowering air bags involved two methods. Both methods assume that the measurement of small differences in chest acceleration on a 50% Hybrid III dummy in 30 or 35 mph barrier crash tests can predict injury and fatality risks.

NHTSA response:

This is not accurate. Approach 1 of the PEA assumes that the distribution of effectiveness of air bags by delta V will be shifted down by 5 mph, when comparing air bags designed to a 25 mph test versus air bags designed to a 30 mph test. Approach 2 of the PEA compares head, chest, and neck responses of the same vehicles tested at 25 and 30 mph and makes assumptions about vehicles designed to a 25 mph standard compared to a 30 mph standard. It appears that this comment and several comments on the following pages relate to the methodologies used in the August 1998 PEA and in the February 1997 FRE. While this methodology is discussed in the October 1999 PEA (see pages A-11 to A-13), it is not the main focus of the analysis and these estimates do not appear in the Executive Summary.

b) DaimlerChrysler states that cadaver tests show air bags permit higher chest g's than manual belts, dummy testing show similar chest g's between air bags and manual belts, yet field data show a much higher effectiveness for manual belts than for air bags.

NHTSA response:

Field data show a much higher effectiveness for air bags at 12 o'clock impacts than in 11 and 1 o'clock impacts. Air bags, without seat belts, are estimated to be about 30 percent effective in direct frontal impacts. Manual belts are estimated to be 45 percent effective in direct frontal impacts. We believe the difference in effectiveness can be explained by the difference in real world conditions, not that chest g's is the wrong indicator of fatality potential. The agency's evaluation[6] showed a good correlation between chest g's and fatality potential.

Manual belts are more effective overall (than air bags alone) in the real world, because they contain the occupant in the seat in a wide variety of crash conditions, they work in multiple impacts, the steering column collapse is not an issue in many lower speed impacts, and they work in crashes from a variety of impact directions.

Appendix 5, pages 8-31 of 67

DaimlerChrysler makes a large number of arguments about the benefits methodology focusing on chest g's used in the February 1997 FRE.

NHTSA response:

While the agency still has faith in these methodologies, they are not the prime methodologies used in the October 1999 PEA. For the most part, DaimlerChrysler questions whether the methodology can be extrapolated from its original data to the test data at hand. This is a matter of subjective opinion. The agency believes its methodology is reasonable, DaimlerChrysler does not. As more data has become available, the agency has changed its methodology to reflect the increase in real world data to get a better estimate of the impacts of the rulemaking.

[6] "Correlation of NCAP Performance with Fatality Risk in Actual Head-On Collisions" NHTSA, January 1994, DOT HS 808-061.